AN EGYPTIAN OASIS

H. J. LLEWELLYN BEADNELL

S. H. Davidson

With the Author's Compliments

AN EGYPTIAN OASIS

AIN ESTAKHERAB, GENNAH.

Frontispiece.

AN EGYPTIAN OASIS

N ACCOUNT OF THE OASIS OF KHARGA IN THE LIBYAN DESERT, WITH SPECIAL REFERENCE TO ITS HISTORY, PHYSICAL GEOGRAPHY, AND WATER-SUPPLY

BY H. J. LLEWELLYN BEADNELL
F.G.S., F.R.G.S., Assoc.Inst.M.M.
FORMERLY OF THE GEOLOGICAL SURVEY OF EGYPT

WITH MAPS AND ILLUSTRATIONS

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TO THE

MEMORY OF A FRIEND AND FELLOW-GEOLOGIST,

THOMAS BARRON,

WHO LOST HIS LIFE IN THE SUDAN

IN FEBRUARY, 1906

PREFACE

The inhabited depressions of the Libyan Desert, called by Herodotus the 'Islands of the Blest,' are interesting alike to the archæologist, to the geographer and geologist, and to the tourist who wishes to wander from the well-beaten tracks, and perhaps none more so than the Oasis of Kharga, lying 130 miles west of Luxor—the site of ancient Thebes—and recently connected by railway with the Nile Valley.

Descended from the ancient Libyans, the inhabitants of the Egyptian oases (numbering over 30,000 souls) are quite distinct from the Fellahin and Bedawin of the Nile Valley. Isolated by arid and desolate wastes, these communities occupy quaint walled-in towns and villages, tucked away among groves of palms, interspersed with smiling gardens and fields of corn. Rain is almost unknown, and rivers are non-existent, the trees and crops being irrigated by bubbling wells, deriving their waters from deep-seated sources.

Kharga—the subject of the present memoir—

formed part of the Great Oasis of ancient days, and was governed in turn by the Pharaohs, the Persian Monarchs, and the Roman Emperors. Through it the ill-fated army of Cambyses is recorded to have marched, and in it is to be seen the most important Persian monument in Egypt, the temple of Hibis. But most interesting of all is the wonderfully preserved Early Christian necropolis, dating from the time of Bishop Nestorius, who was banished to Kharga in A.D. 434. Juvenal, Athanasius, and other celebrities likewise appear to have made unwilling acquaintance with this portion of the Roman Empire.

The character of the people at the present day—a curious mixture of stupidity, apathy, and shrewdness—seems to reflect in great measure their past history, as well as the peculiar conditions under which they still live. A history of the inhabitants since the withdrawal of the Roman garrisons would resolve itself into an account of an endless combat with Nature, which, with sand and wind as its chief agents, has never abated its efforts to recover those tracts which the Ancients, by the exercise of much skill and industry, wrested from the desert.

As a member of the Geological Survey of Egypt from 1896 to 1905, I spent nearly nine years in survey and exploration work in the Egyptian deserts, and for the past three years I have been in charge of extensive boring and land-reclamation

operations in the particular oasis with which this book deals, so that I have had exceptional opportunities of studying at first hand a region of peculiar interest. Among other questions dealt with are the vast systems of subterranean aqueducts constructed by the Romans; the extensive lakes which occupied the floor of the oasis-depression well into historic times; the rate and mode of movement of desert sand-dunes; the formation and gradual elevation of the cultivated terraces by the constant accumulation of wind-borne material; and the deep-seated water-supplies, a subject which, in view of recent discussions as to the origin of the artesian waters of arid regions, is of more than local interest.

Some portions of the book, more especially those dealing with geology and water-supply, have already been published in somewhat different form in the *Geological Magazine*, and I am indebted to Dr. Henry Woodward, F.R.S., for permission to reproduce them, as well as the plate showing Bore No. 39 and the geological section across the oasis.

The illustrations are reproduced from photographs taken by me at different times during the last few years. The maps, showing the relative positions of the oasis and the Nile Valley, the caravan roads, and the geology, have been compiled from all available published material, chiefly the work of Dr. John Ball and myself. Some portions of these, as well as the plan showing

the subterranean aqueducts of Um El Dabâdib, are now published for the first time. The caravan routes, while shown with sufficient accuracy for all practical purposes, have not been surveyed with the same degree of exactness as the other details shown on the maps.

H. J. LLEWELLYN BEADNELL.

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THE LIBYAN DESERT AND ITS OASES

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No more striking contrast can be imagined than that between the intensely cultivated Valley of the Nile and the barren deserts on either side. There are arid wastes in many parts of the world—in Australia, in the Western States of America, in Asia—but in point of desolateness, in the absence of animal and vegetable life, there is probably nothing to rival the greater portion of the Libyan Desert, on the west side of the Nile. Its barrenness is aggressive; it is not necessary to travel far to make its acquaintance; so sharp is the junction that, in a single step, one may pass from the richly cultivated alluvial soil of the Nile to the bare sandy plains which skirt the more rocky interior of the desert. Along the borders of the

Egyptian wastes one generally looks in vain for the Persian poet's

> "Strip of herbage strown,
> That just divides the desert from the sown."

Geographically the Libyan Desert is the eastern and most inhospitable portion of the Sahara, or Great Desert of Africa. On the north and east its boundaries are clearly defined by the Mediterranean Sea and the Valley of the Nile; on the south it is bounded by the Darfur and Kordofan regions of the Egyptian Sudan; to the south-west its limits may be regarded as coterminous with the elevated districts of Tibesti; while on the west it stretches to the outlying oases of Fezzan and Tripoli. Its area is about 850,000 square miles, or approximately seven times that of the British Isles.

With the exception of a narrow belt fringing the Mediterranean, the region is, to all intents and purposes, rainless, the occasional thunderstorms being extremely local, and seldom breaking over the same district in two consecutive years. In the more elevated deserts on the eastern side of the Nile rains appear to be of sufficiently frequent occurrence to maintain a water-supply in the isolated water-holes and valley-springs, and to allow of the growth of a fairly permanent though scanty herbage in the more favoured areas. The Eastern desert does, therefore, to some extent, support a migratory Arab population. On the other hand, the greater portion of the Libyan

Desert is quite devoid of vegetation and water-holes, and is, in consequence, uninhabited even by nomad tribes. At the same time, the extreme barrenness of the region as a whole is in great measure counterbalanced by a number of isolated fertile oases, in which there is a permanent resident population, deriving its water-supplies entirely from underground sources.

The term 'oasis,' an ancient Egyptian word signifying a resting-place, in its strict sense means a fertile spot in a desert, but in Egypt has usually been applied to a depression as a whole, each individual cultivated area being known by the name of the well from which its water is derived. The chief groups of oases in the Libyan Desert are the Siwan on the north, that of Kufra on the west, and the Egyptian, including the four large oases of Baharia, Farafra, Dakhla, and Kharga, on the east. The present volume deals more especially with the last of these.

The Libyan Desert is primarily divisible into two entirely different parts, distinguished by the presence or absence of surface accumulations of blown sand. Extensive dunes are confined to the western portion, where areas of hundreds of square miles are literally buried under deep seas of sand, blown into more or less parallel dunes of great height, lying N.N.W. and S.S.E., in the direction of the prevailing winds. In this country it is almost impossible to travel in a latitudina direction, so that the sand-covered area forms an

effective barrier between the Egyptian oases and Kufra, one of the strongholds and, at any rate until recently, the headquarters of the powerful Senussi sect. It is probable that, within the last century, the area of this sand has extended considerably to the south, as an old caravan road trending westwards, and believed to have originally connected the oases of Dakhla and Kufra, is now lost in the dunes. As long ago as 1874 some of the members of the Rohlfs expedition made an attempt to penetrate westwards from Dakhla, but on reaching the edge of the great sand-region, about 170 kilometres W.S.W. of Qasr Dakhl, were compelled to turn northwards and travel in a direction parallel to the lines of dunes, from which they emerged, after a long and wearisome journey of 400 kilometres, in the neighbourhood of the oasis of Siwa. Outlying portions of this sand invade the Egyptian oases; for instance, the depression of El Daila, lying to the west of Farafra, is to a great extent filled with blown sand, while an extensive area in the south of Farafra itself is buried under dunes.

On the eastern portion the sand is for the most part confined to isolated lines of dunes, the most remarkable being that known as the Abu Mohariq. This commences in latitude 29° 45′ north, at Arûs el Buqar, some 50 kilometres south-west of the Mogara swamp, in the low country to the south of the great east and west Miocene escarpment. From Arûs el Buqar the Abu Mohariq sand-belt

runs in an almost straight and unbroken line across the Libyan plateau to the oasis of Kharga, through which it continues into the desert to the south. The average breadth of this line of dunes is only some 6 or 7 kilometres, whereas its length cannot be less than 650. Less extensive accumulations of blown sand are found in the oases themselves, in the depressions of Gharaq and Muailla to the south of the Fayûm, and encroaching on the cultivated lands of the Nile Valley between Bahnessa and Mellawi.

The eastern part of the Libyan Desert, in which are situated the Egyptian oases, is itself divisible into three areas having essentially different characters, the northern being an undulating rolling country of sandstones, grits, and gravels ; the central consisting of bare elevated limestone plateaux ; the southern a lower-lying expanse of rugged sandstone, broken only occasionally by ridges and bosses of granite and other crystalline rocks.

The Egyptian oases are deep and broad hollows or depressions in the Libyan Desert plateau. In position they appear to coincide with areas where rocks of comparative softness became exposed at the surface during the gradual lowering of the country by denudation. At such points the general rate of weathering must have become greatly accelerated, with the result that those vast depressions, which form such conspicuous features in the configuration of the country at the present day, were eventually cut out.

Underlying the greater part of the Libyan Desert are porous sandstones, and these, when pierced by deep borings put down from the lower-lying parts of the floors of the depressions, yield abundant supplies of water of remarkable purity. As these sandstones, as well as the shales with which they are associated, have a general dip or inclination from south to north, we are led to infer that they outcrop or come to the surface to the south, so that in all probability the water with which they are so highly charged has its origin in that direction. Whether the water obtains access to the sandstones by direct infiltration of the rains of Abyssinia or the Sudan, from the swamps of the sudd region of the Upper Nile, or from the Nile itself in the Nubian reaches, has not yet been decided with certainty. Recent observations, however, show that far more water is lost in some reaches of the Nile than can be accounted for by irrigation and evaporation, and it seems probable, therefore, that the excess disappears by infiltration into these sandstones.

Little is known of the early history of the oases, though the remains of ancient towns and cemeteries are abundant, and only await systematic excavation by Egyptologists to bring our knowledge of this part of Egypt into line with that of the Nile Valley. That the oases were inhabited in prehistoric times is evident from the occurrence of flint implements of Palæolithic types, both on the margins of the surrounding plateaux and within the depressions, though there is not at present sufficient evidence to

enable us to affirm that the makers and users of these flints were contemporaneous with Palæolithic man in Europe. Implements of Neolithic type, often of finished workmanship, are, moreover, common in places on the floors of the depressions, but it is probable that these were in use well into the historic period.

In historic times the oases, according to Sayce, were governed by Egyptian Kings in the eighteenth dynasty (1545-1350 B.C.), and the oldest monuments as yet found in the oases-depressions date from this period. The most important of the earlier remains belong, however, to the Persian epoch, notably the temple of Hibis near the modern village of Kharga, which was built by Darius. Ptolemaic remains are also known in Kharga, but the greater number of the historical monuments date from the time of Roman occupation, when the oases appear to have attained a considerable degree of prosperity, which continued to Coptic times. Since the Mohammedan conquest of Egypt they have fallen into a state of neglect, and with the consequent diminution of the water-supply the population has decreased, and large areas of formerly fertile country have been absorbed by the surrounding desert.

It is interesting to speculate on the conditions which obtained in Kharga before the first borings were made, as at the present day we cannot point, so far as I am aware, to a single natural efflux of water on the floor of the depression. Surface-

water, of quite a different character from the deep-seated water, is met with at comparatively shallow depths in various localities, and may either represent drainage water from the flowing wells and cultivated tracts, or be water which has escaped from the underground sandstones and found its way to the surface through fissures. Probably it is derived from both sources. In prehistoric times natural springs fed through fissures may have existed here and there within the depressions; and in any case it is probable that prehistoric man obtained sufficient supplies by sinking wells into the upper sandstones, which in some parts of the oasis occur at or near the surface, and contain large quantities of sub-surface or sub-artesian water. Nothing is known as to when flowing wells were first obtained, or by whom the original deep borings were made, and no traces of the implements used have been discovered. Many of these ancient wells, frequently over 120 metres in depth, continue to flow at the present day, although in most cases with a greatly diminished output; a few, however, are still running day and night at the rate of several hundred gallons a minute.

In some parts of the oases water-bearing sandstones occur at or near the surface, and from these beds the Romans obtained additional supplies by the excavation of underground collecting tunnels. Subterranean works of this description are found in all the oases, the most remarkable being in Baharia and at Um el Dabâdib and Jebel Lebekha in

Kharga. They are frequently of great length, cut throughout in solid rock, and connected with the surface above by numerous vertical air-shafts. Many of the latter measure from 30 to 50 metres in depth, so that the construction of these and the horizontal carrying channels must have involved an immense amount of labour.

In Roman times water-stations appear to have been maintained at frequent intervals on the desert roads between the oases and the Nile Valley, and a great development of the water-supply took place. After the Arab invasion, however, no attention seems to have been given to irrigation works, the wells, owing to silting, becoming gradually choked up. As the result of this neglect the water-supply diminished to such an extent that a large portion of the population was compelled to emigrate to the Nile Valley, and even the remaining inhabitants were scarce able to raise sufficient supplies for their maintenance. Within the last fifty years a considerable number of new wells have been made by means of simple hand-boring appliances sent out by the Egyptian Government; most of the new bores have been very successful, but latterly, through want of effective supervision, a great deal of harm has been done by promiscuous boring. Moreover, a very large amount of water is wasted owing to the wells not being fitted with regulating and closing appliances; the water, when not required for irrigation, continues to run, finding its way to the low-lying lands, and forming swamps which

furnish ideal breeding-grounds for fever-carrying mosquitoes.

Within the last year or two this part of Egypt has received renewed attention; extensive boring operations and land reclamation works have been commenced, and the oasis of Kharga has been brought into railway communication with the rest of Egypt.

The floor-level of the oases varies considerably, but in general the cultivated lands lie between 30 and 120 metres above sea-level. The exact area under cultivation is only known very approximately, but it is certain that with an increased water-supply it could be very much augmented. The existing water-supply is totally insufficient to irrigate the available lands, and such portions of the latter as are tilled are generally left fallow in alternate years, and in many cases are only under crops once every four or five years. Now that an attempt is being made to restore the oases to their former prosperity, the question of ownership of land has become of the greatest importance, and it is one bristling with difficulties. As a general rule the wells are owned collectively, the different proprietors having the right to utilize the flow for periods corresponding to the extent of their holdings in the well. Individual shares may amount to as much as one-third or one-half of the well, or be only the merest fraction; in the latter case the small holders combine so as to obtain control of the flow for an appreciable period. Frequently the

whole of the land irrigated by a well is cultivated collectively, the crop on reaping being divided among the owners in portions corresponding to their shares of the water. The question of ownerships is further complicated by there being persons who own water but no land, and by others who claim land but own no water.

CHAPTER II

EARLY RECORDS

Travellers' Names inscribed on the Monuments—Poncet passes through Kharga *en route* for Ethiopia—Browne—Cailliaud's Extensive Researches—Drovetti—Sir Archibald Edmonstone, Bart., discovers Dakhla Oasis—Hoskins—Exaggerated Opinions of Ancients regarding the Oases—Names of Explorers on the Walls of Hibis—Rohlfs' Expedition—Zittel's Geological Work—The words 'Oasis,' 'Wah,' 'Otu,' and 'Set-ament'—A Theban Myth—Dr. Schweinfurth—Brugsch Bey—Captain H. G. Lyons—Government Survey of the Oases—Dr. John Ball.

Inscribed on the walls of the ancient monuments in the oasis one frequently comes across the names of travellers who visited the same scenes fifty, a hundred, or even two hundred years ago. Many of these explorers wrote descriptions of their travels and experiences, and such early records are naturally of the greatest interest and importance; unfortunately they are now out of print and somewhat difficult to procure, so that I make no apology for briefly referring to those which I have been able to examine. Most of these early records are extremely quaint, and although they are chiefly descriptive of the personal experiences and impressions of the writers, in some cases numerous observations are

recorded in a sufficiently exact manner to be of permanent scientific value.

A French physician, Monsieur Poncet, who passed through Kharga in 1698, *en route* for Abyssinia, appears to have been the only traveller who left any written records of the Great Oasis between the sixteenth and nineteenth centuries. A translation of the account of his travels was published in English in 1709 ('A Voyage to Æthiopia'). Accompanied by one Hagi Ali, an officer of the Abyssinian Emperor, and by a Jesuit missionary, Father Charles Francis Xaverius de Brevedent, Poncet set out from the town of Manfalut in the Nile Valley, and travelled along the Derb el Arbaîn, the well-known caravan route to the south. His description of this portion of the journey is as follows:

"We set forward on the 2d of October early in the Morning, and from that very Day we enter'd a frightful Desart. These Desarts are extremely dangerous, because the Sands being moving are rais'd by the least Wind which darken the Air, and falling afterwards in Clouds, Passingers are often buried in them, or at least lose the Route, which they ought to keep."

Poncet refers to the oasis as 'Helaoue,' but although his caravan rested there four days, before proceeding to Dongola, via Shebb and Selîma, he makes no reference to the antiquities; in fact, his remarks on this region are extremely meagre. To quote his own words: "We Arriv'd on the 6th of

October at Helaoue; 'Tis a pretty large Borough, and the last that is under the Grand Signior' Jurisdiction. There is a Garrison in it of 500 Janisaries and 300 Spahi's under the Command of an Officer whom in that Country they call Kachif. Helaoue is very pleasant, and answers fully its Name, which signifies a Country of Sweetness. Here are to be seen a great Number of Gardens water'd with Brooks, and a World of Palm-trees, which preserve a continual Verdure, Coloquintida is to be found there, and all the Fields are fill'd with Senna, which grows upon a Shrub, about three Foot High. This Drug which is so esteem'd in Europe, is of no use in the Country hereabouts. The Inhabitants of Helaoue in their Illnesses, make only Use of the Root of Ezula, which for a whole Night they infuse in Milk, and take the day after, having first Strain'd it thro' a Sieve. This Medicine is very Violent, but 'tis what they like and commend very much. The Ezula is a thick Tree, the Blossom of which is blue; it grows into a sort of Ball, of an Oval Figure, full of Cotton, of which the People of that Country make pretty fine Cloth."

Referring to the deserts which surround the oases, Poncet remarks: "Those vast Wildernesses, where there is neither to be found Bird, nor wild Beast, nor Herbs, no nor so much as a little Fly, and where nothing is to be seen but Mountains of Sand, and the Carcasses, and Bones of Camels, Imprint a certain horrour in the Mind, which makes this Voyage very tedious and disagreeable.

It wou'd be a hard matter, to Cross those frightful Desarts without the Assistance of Camels. These Animals will continue six or seven Days, without either eating or drinking, which I cou'd never have believ'd, if I had not observ'd it very particularly." Poncet further relates that he was assured by a venerable old gentleman of his caravan that camels had been known to cover a desert journey of forty days and nights without either food or water. Although it is to be feared that the 'ship of the desert' at the present day is scarcely so abstemious as formerly, we must admit that Poncet's description of the sterility of the Libyan Desert is little, if at all, exaggerated. One may, indeed, travel for hours without seeing bird, beast, or herb ; and even 'the little fly,' which seldom fails to make known its presence for some time after leaving the inhabited districts, generally forsakes one before the caravan has proceeded far into the depths of the desert.

W. G. Browne traversed the same route nearly a hundred years later, passing through the oasis in June, 1793. He relates how he entered the depression at the northern extremity, at the pass known as El Ramlia, and camped at Ain Dizé (probably in the neighbourhood of the modern Ain el Qasr), eight hours' march from Kharga. Browne passed through the depression from north to south, visiting Kharga, Bulaq, Beris, and Maks, whence he followed the usual route to Shebb and Selîma. Like his predecessor, he makes no mention of the antiquities.

Cailliaud, a young French mineralogist, explored Kharga in 1818, and to him we owe the earliest published detailed descriptions and illustrations of the chief antiquities of the oasis. As the existence of important monuments in the oasis was at that time quite unsuspected, Cailliaud's work attracted considerable attention, and his drawings and descriptions were purchased and published by the French Government and dedicated to the King. Cailliaud set out from Esna in the Nile Valley and crossed the Libyan plateau to the village of Jaja. After visiting the most southerly villages of Dush and Beris, he journeyed northwards to Kharga, then, as now, the chief village, whence, on the completion of his researches, he returned to Farshut on the Nile, via Dêr el Ghennîma and the Wadi Samhûd. Cailliaud's observations are almost entirely confined to the archæology of the oasis, and his writings yield little information regarding the villages, wells, and cultivated lands.

The Chevalier Drovetti, French Consul-General in Egypt, visited Kharga the same year as Monsieur Cailliaud. He started from Beniâdi, following the Derb el Arbaîn caravan route southwards, and entered the depression at the northern extremity. Drovetti traversed the oasis from north to south, and proceeded thence to Dongola. Later, on his return journey, he crossed the depression in the opposite direction, eventually returning to the Nile Valley by way of the oasis of Dakhla and the Derb el Tawîl.

A PASS INTO THE OASIS.

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In 1820 Cailliaud again passed through Kharga. He had explored the oasis of Siwa the previous year, whence he travelled, via Baharia and Farafra, to Dakhla, and thence past Ain Amûr to Kharga village. On this occasion no further researches were undertaken in the depression.

Sir Archibald Edmonstone, Bart., accompanied by two friends, visited Dakhla and Kharga in 1819, and constructed a rough but fairly accurate map, showing the relative position of the two oases, with their bounding escarpments and principal villages. Their situation in the Libyan Desert, with regard to the Nile Valley, is, however, greatly in error, being shown fully a degree too far west and nearly half a degree too far north. Edmonstone followed the Derb el Tawîl route from Beniâdi in the Nile Valley to the village of Belat in Dakhla, returning by the Ain Amûr road to Kharga, and thence to Farshut. The major portion of the account of his travels refers to Dakhla, of which oasis he must, indeed, be regarded as the modern discoverer.

Hoskins explored Kharga in 1835, and published a most valuable and engaging account of his travels a couple of years later. This work, entitled 'Visit to the Great Oasis of the Libyan Desert,' contains a number of illustrations depicting the scenery, the chief monuments and their hieroglyphics, etc., made from original drawings and paper casts. Many of the inscriptions are given in full, both in the original and translated into English, and the work of all previous writers and explorers is carefully

summarized. In some cases I have verified the accuracy of Hoskins' drawings by comparing them with photographs taken from the same points, and have been much struck with the insignificant amount of decay which some of the buildings have undergone during the course of over seventy years.

Rizagat, near Thebes, was Hoskins' starting-point, and he entered the depression by the Bulaq pass, crossing the oasis-floor to the eminence known as El Gorn el Gennâh. Surveying the oasis from this point of vantage, Hoskins remarks that the attractions of the cultivated portions of the depression, those

"Tufted isles that verdant rise amid the Libyan waste,"

are apt to be exaggerated, owing to their great contrast to the surrounding deserts. "The fair appearance then of this oasis is in a great measure fictitious; and has chiefly its origin in the relief afforded to the mind, wearied by the monotony and dreariness of the surrounding wastes. It seems to me therefore, that the only rational way of accounting for the exaggerated epithets which the ancient writers and some modern travellers have applied to this district, is to attribute them to their surprise, at finding in such a fearful region any verdure, any habitable spot, and to the exhilarating effect on the spirits of this agreeable contrast to the dreary deserts which they have just crossed. But comfortless as was my journey through the wilderness, and beautiful as the woods

of palm-trees, doums, and acacias in the Oasis certainly are, still the vivid recollection of the superior loveliness of the banks of the Nile, prevents my consenting to call these regions 'the Gardens of the Hesperides'; and sadly must the oasis have diminished in beauty, if it ever merited the praise which Herodotus bestowed upon the place, in calling it 'the Island of the Blessed.'"

Hoskins, who was accompanied by two other Englishmen, made splendid use of the fortnight spent in the oasis, although unfortunately, just before the termination of his visit, he sustained a violent attack of fever. Their departure is thus described: "After ascending the mountain which bounds the Oasis, we lingered some time at the summit, to take, I may certainly say, our last view of the place; for having, as the Arabs say, got all its antiquities on paper, and having providentially once escaped its pestilential atmosphere, we shall never, I think, by any possibility, have the slightest inclination to revisit such a baneful region."

Most of these early explorers found time to cut their names on the walls of the temple of Hibis, and Cailliaud must have spent hours in this occupation, as he has left a long and neatly executed inscription recording himself as the original and genuine discoverer of that noble edifice. The names of these explorers, who in some cases suffered considerable hardships in visiting the oases, are, however, quite overshadowed by the numberless scrawls made in recent years by a host of otherwise unknown

petty officials of the Government, who have had to take their turn of duty and banishment in the greatly dreaded desert. The dated names cut in the walls of the temple are of some value, as an examination of them frequently yields reliable evidence of the rate of weathering of the stone since the time at which they were inscribed.

It was not until after the winter of 1873-74, when the great German expedition, under the leadership of Rohlfs, with Zittel, Jordan, and Ascherson as geologist, topographer, and botanist respectively, visited all the chief oases of the eastern portion of the Libyan Desert, that any connected scientific observations of importance, other than those dealing with archæology, were published. The Rohlfs expedition astronomically determined the positions of selected points in each oasis, and produced a map on which the principal villages and the approximate limits of the depressions were correctly shown. Zittel at the same time worked out the general relations of the different geological formations found in the country, described their main divisions, and indicated approximately the areas occupied by them. So thoroughly, indeed, did this expedition accomplish its mission that its results have formed a sound basis for all later scientific work in this part of Egypt.

As the voluminous memoirs recording the observations of the members of the Rohlfs expedition are easily obtainable at the present day, it is unnecessary here to do more than briefly

refer to a few of their more general remarks on the oasis of Kharga. In his 'Three Months in the Libyan Desert,' Gerhard Rohlfs states that he and his companions travelled from Dakhla Oasis by the Ain Amûr road, and were greeted at Kharga village by Schweinfurth, who was for the time being residing in a disused alum factory. Rohlfs spent only two or three days in the neighbourhood of Kharga, and remarks that the expedition did not undertake detailed work on the antiquities, as the latter had already been so competently described by Hoskins and other previous explorers; a few corrections and amendments of published accounts of the temple were, however, made. The splendid preservation of the Christian necropolis, with its mausolea of unburnt brick, is remarked upon, and Rohlfs adds that, in beauty and ingenious arrangement, this burial-ground can only be excelled by the necropolis of Cyrene.

Rohlfs describes Kharga village as being pretty from a distance, but remarks that the narrow dirty alleys are the pictures of laziness and poverty; the streets are covered in for protection against the rays of the sun, a common practice throughout the Sahara.

The word 'oasis' is old Egyptian, as also is the Arabic 'wah,' the latter word being also found in Coptic, and signifying an inhabited place; nevertheless, the word 'wah' was never used by the ancient Egyptians to designate the oases. These they called 'otu,' which means a place where

bodies are embalmed. 'Otu' has its origin in the Theban myth, according to which Seth, the murderer of Osiris, was pursued by Horus to Koptos, where he was captured and thrown into a dungeon. His corpse was afterwards found by his friends, and taken to the oases for burial.* The inscriptions on the temple of Hibis in Kharga refer to the oases under the comprehensive name 'Set-ament,' the 'Western Lands.'

About the same time Dr. Schweinfurth, whose services to Egypt in so many branches of science stand pre-eminent, published important contributions on some of the archæological remains. Two or three years later Brugsch Bey brought out an account of the antiquities of the oasis, with translations of a number of the inscriptions on the temples of Nadûra and Hibis. The antiquities will be briefly referred to in my account of the history of the oasis under the Persians and the Romans, and for fuller details the reader is referred to the publications of Cailliaud, Hoskins, Schweinfurth, Brugsch, and some still later writers.

In 1893-94 Captain H. G. Lyons, R.E., in the course of a military patrol, undertaken in order to ascertain the measures necessary to protect the inhabitants of the oasis from possible Dervish raids, made valuable geological observations on the Eocene and Cretaceous systems, especially in relation to the connection of folding and water-supply.

* This legend is stated by Rohlfs, on Brugsch's authority, to be recorded on the temple of Horus at Edfu.

These he discussed in a paper read before the Geological Society of London in 1894, and it was mainly due to the interest it aroused, and to his initiative in pointing out to the Egyptian authorities the importance of having a comprehensive examination of the country carried out, that the Geological Survey of Egypt was established in 1896.

The detailed survey of the Libyan Desert was taken up in October, 1897, and completed in June of the following year, the four oases being mapped on the scale of 1 to 50,000 by plane-table triangulation, checked and adjusted by numerous astronomical observations. Direct measurements by measuring-wheel were also employed to a considerable extent. Baharia Oasis was the first to be taken in hand, Mr. Leonard Gorringe and I taking the western side, and my colleagues, Messrs. Ball and Vuta, the eastern. This plan of splitting up an oasis-depression between two surveying parties was not, however, found satisfactory, and on the completion of Baharia it was decided that Ball should take up the oasis of Kharga, while Farafra and Dakhla fell to my lot. The results of this survey are published in the Memoirs of the Geological Survey of Egypt.

During the last three years I have been fortunate in having had opportunities of studying in some detail the topography, geology, and water-supply of the oasis of Kharga. This detailed examination has enabled me to revise and amplify pioneer work, and has, in certain instances, forced me to differ

from the opinions expressed by my predecessors in the same field, views which, in the light of the evidence available at the time, were doubtless well justified. In the same way may future research necessitate the modification or alteration of the conclusions herein expressed, and for many years to come the region of the oases will offer a vast field for further scientific work.

Before concluding this brief account of the literature on the oasis of Kharga, I should like to take the opportunity of expressing my high appreciation of the energy and purpose of my former colleague, Dr. John Ball, who, in spite of the many hardships and difficulties inseparable from scientific work in the Libyan Desert, in such a short time accomplished so much.

CHAPTER III

THE ROADS LEADING TO THE OASIS

Lines of Communication between the Nile Valley, Kharga, and Dakhla Oasis—Principal Passes out of the Oasis—Ascent to Plateau with Caravans—Main Roads to Assiut, Sohag, Karnak, Esna, and Edfu—Nature of intervening Plateau—Ghubbâri Road to Dakhla—The Upper or Ain Amûr Road—The Railway between the Nile Valley and the Oasis—Nature of Desert Roads—The Bedawin Arabs—Cross-Country Traverses as the Crow flies—Traverse from Farafra to Assiut—Rate of Travelling with Camels.

THE oasis of Kharga is in communication with Dakhla to the west, and with the Nile Valley to the east, by a number of caravan routes, the most frequented of which connect directly with the two villages Kharga and Beris, in the north and south of the depression respectively. Formerly, everyone bound for the oasis was compelled to undertake a four or five days' journey along one or other of these routes, and although nowadays most persons will elect to cross the plateau by train, a description of the oasis would be incomplete without some reference to the desert roads.*

* Reference to the plan showing the different roads and passes out of the oasis-depression will facilitate the perusal of the following pages.

The depression is for the most part bounded by steep and lofty escarpments, quite inaccessible to camels, except at a few points where the gradients are less severe, and the loose blocks of rock and other cliff débris have been removed. The principal passes up the eastern scarp of the oasis are seven in number, the most northerly, known as El Ramlia, being in the extreme north-east corner of the depression. Thirteen kilometres south of this is El Yabsa pass. The next is the Refûf, at the head of the gully 45 kilometres north-east of Kharga village. A little farther south, east of the old Roman fort near the foot of Jebel Ghennîma, one of the two prominent outliers of the eastern plateau, is the pass of Abu Sighawâl, and 35 kilometres to the south is the Nagab Bulaq, N.N.E. of the village of Bulaq. In the south end of the oasis there are passes to the north-east of Jaja, and N.N.E. of Dush. These seven passes are the main exits from the depression on the east side, though there are several other little-used routes, up which lightly laden camels can be taken, for instance, near Jebel Um el Ghennaim. The illustration showing the descent to the depression was, in fact, taken at one of the latter.

Although the roads ascend the escarpments at the best available points, in some cases taking advantage of the easier gradients of the extensive cake-like masses of calcareous tufa, which in places have been deposited over the face of the original cliffs, their ascent with heavily laden camels may at

times become somewhat of an undertaking. The paths are frequently rough, and the difference in height between the foot of the scarp and the plateau is usually between 200 and 300 metres. The pack-saddles should always be carefully adjusted and secured by ropes passing round the base of the neck or below the butt of the tail, according to whether the caravan is making the ascent or descent; otherwise the loads are likely to slip off, and the restricted limits of a steep path, in the middle of a train of camels, is not an ideal place for their readjustment. In hot weather the ascent to the plateau, though perhaps occupying only one or one and a half hours, will take as much out of the pack-animals as a whole day's march. I experienced no little trouble on one occasion when returning to the valley after some months' survey work in Dakhla Oasis. After halting one day at Kharga village, we proceeded on our way to Esna by the Bulaq pass. It was hot weather, towards the end of May, and the ascent of the pass tired our camels, naturally not in the pink of condition, to such an extent that Gorringe and I had some difficulty in getting them across the plateau to the valley. In summer-time it is always advisable to negotiate this part of the journey in the early morning or late in the evening, unless the heavier portion of the baggage can be sent in advance to the top of the scarp, and the animals taken back and watered at the nearest well.

The main roads from the oasis run to Assiut, Kawâmil near Sohag, Waled Hallaf near Girga,

Karnak near Farshut, and to Rizagat, Esna, and Edfu, and their disposition may be seen on the accompanying plan.

The Assiut road, after leaving Kharga village, passes the hamlet of Meheriq and follows the line of wells to Ain el Ghazâl, which is the last place at which water-skins and tanks can be filled. From Ain el Ghazâl the most direct route ascends to the plateau by the Ramlia pass in the extreme corner of the depression, but the Yabsa exit is recommended as easier and very little longer. After crossing a tract of country with an abominably rough surface, the two tracks unite a few kilometres north of the depression, and about a day's march farther on the Zarâbi road takes off on the right. The main road proceeds direct to Assiut, descending the scarp about 8 kilometres before the town is reached, a by-path to the little village of Dronka having branched off beforehand.

From the summit of El Yabsa a separate road proceeds direct to El Ghennaim, a village on the edge of the desert to the north-west of Tahta. By these roads the distances from Kharga village to Assiut, Zarâbi, and El Ghennaim, are 210, 200, and 180 kilometres respectively.

El Refûf, the pass by which the Sohag (Kawâmil) road leaves the depression, is situated at the head of a gully, and offers an easy ascent to the plateau. A few kilometres beyond, the road passes to the north of El Shugera, a prominent detached block perched on end at the foot of the southern slope of

a small limestone range. The road runs in a fairly steady direction 40 degrees north of east, striking the Nile Valley scarp 15 kilometres before Kawâmil, on the edge of the cultivated lands, is reached. About 33 kilometres before reaching the scarp a branch takes off and runs nearly due north to Guhêna, south of Tahta; this branch is, in fact, usually referred to as the Tahta road.

If the traveller, after leaving the Refûf pass, keeps to the south of El Shugera, he will find a branch road leading to El Tundaba, a deep shaft in the centre of the plateau, at kilometre No. 92 on the railway; a little farther east this track strikes the main road from the Abu Sighawâl pass. The shaft is sunk through a thick deposit of silt, which has filled a local depression in the plateau to some depth. The silt must be regarded as rain-wash from the surrounding country, possibly deposited in the time of prehistoric man. Flint implements are to be found scattered about, and from the presence of pottery and graves it would seem that the place had been inhabited in comparatively modern times. The pit was evidently sunk for water, although at the present time it is quite dry; given, however, a heavy thunderstorm within the catchment-basin, drainage-water would in all probability find its way to the bottom of the deposit, where it would be held up by the limestone, and might form a supply lasting possibly for many years.

The road leaving the depression by the Abu Sighawâl pass, and leading to villages in the neigh-

bourhood of Girga and Farshut, is reckoned the best and shortest route between Kharga and the Nile Valley, and, by making a very short détour, caravans have the advantage of being able to water at the old Roman fort at the base of Jebel Ghennîma, 27 kilometres after leaving the village. The ascent of the pass was formerly very rough going, but a good road with an easy gradient has recently been cut for the transport of heavy boring machinery into the oasis. From the top of the Abu Sighawâl pass a well-marked track crosses to El Refûf and connects with the Sohag road, and care has to be taken by travellers for Waled Hallaf, El Elwania and Karnak not to make the initial mistake of getting on to this track.

For the first few kilometres the main road from Abu Sighawâl runs very straight over a level plain, on which fossil sea-urchins are so abundant as to attract the attention of the most casual observer; it then ascends a low escarpment, the Nagab el Jellab. The somewhat rough limestone country beyond is known as the Mishâbit, and then El Botîkh, with its countless millions of spherical chert concretions, is crossed. Beyond El Botîkh the road passes an isolated limestone hill called El Mograbi, where tradition has it that a Mograbi Arab from the west and his stolen oasis bride were overtaken and decapitated by the Kharga people. A little farther to the east there is a bifurcation, but the branches soon rejoin, and after passing El Masaâd the plain is fairly level, though covered

with very angular blocks of crystalline limestone and cherty concretions. Farther on are the rocks of El Buraig, where large quantities of broken pottery indicate the site of one of the many water-stations maintained by the Romans along this road. Garat el Melh is so called from the occurrence of salt in the limestones of this locality. A few kilometres to the east of Garat el Melh the road passes El Suâga, an artificial heap of stones to which every self-respecting Bedawi is careful to contribute; and a couple of hours beyond, a fairly conspicuous limestone hill, called Garat Radwan, is reached.

Shortly after passing Garat Radwan the most prominent landmarks met with on this road, in the form of two solitary crescent-shape sand-dunes, loom into sight; these are called El Ghart by the Arabs and are distant 55 kilometres from Abu Sighawâl. They form part of a belt of single isolated dunes which crosses this part of the desert in a N.N.W. and S.S.E. direction. The same line of dunes is passed by the railway at kilometre No. 100, and I have observed its continuation still farther north on the Sohag road, at a point 45 kilometres from the Refûf pass. These dunes mark the entrance to an area of very rough hummocky crystalline limestone known as El Zizagat, through which the track is not easily followed. On emerging from El Zizagat the road bears slightly to the north, and is here only a few kilometres south of El Tundaba. At this point it bifurcates,

the northern branch proceeding direct to Waled Hallaf near Girga, the southern continuing over the easy level plains of El Ishab to the rocks of El Baglûli, and thence past those of Dilail el Kelb to the twin hillocks of Dubîya. Beyond El Dubîya the road crosses the shallow drainage-line of Rod el Ghanam, near the head of the Wadi Samhûd, down which it passes, and thence over the Nile Valley plains past El Hamera and Hagar Hawara to Karnak and Farshut.

It should be mentioned that at Rod el Ghanam, shortly before reaching the head of the Wadi Samhûd, a branch road takes off on the left-hand side and descends by a separate pass to El Elwania; and here again care has to be exercised to avoid taking the wrong branch, as the tracks cover a broad area, and the actual junction may be easily missed.

The Kharga-Waled Hallaf road, via the Abu Sighawâl pass, is the shortest route from the oasis to the Nile Valley, the distance being only 160 kilometres; that to Karnak, by the Wadi Samhûd, is somewhat longer, being approximately 174 kilometres.

The next pass of importance to the south lies east of the village of Bulaq, whence it takes its name. From the summit a road runs nearly due east, meeting a second, starting from Beris and gaining the plateau by the Jaja pass, after one and a half days' march. From the cross-roads, 'El Mafâriq,' routes run direct to Farshut and Rizagat.

From Beris to Farshut, by the Jaja pass, the distance is approximately 224 kilometres; from Kharga, by the Bulaq pass, the roads to Farshut and Rizagat measure about 203 and 198 kilometres respectively. Another road from Beris leaves the depression by a pass to the east of the village of Dush; this bifurcates about two days' march from the latter, the left-hand track leading to Esna, the right to Edfu. Other roads lead from the south end of the oasis, via Nakhail, to Kurkur and Dungun, while the Derb el Arbaîn runs southwards to Selîma and thence on to the Sudan.

The road between the oasis and Assiut is best known as being the last and worst portion of the Derb el Arbaîn, or forty days' road, which, starting from Darfur, was originally one of the main lines of communication between Egypt and the Sudan. It was along this desert route that great numbers of slaves and large quantities of merchandise, such as ivory, gum, and other products of the Sudan, were imported into Egypt from the south. After passing the last spring in the oasis, caravans had still a little over 200 kilometres to cover before reaching the Nile Valley, with a steep ascent to the plateau at the outset, and thence for a considerable distance over the very worst surface imaginable—loose sand full of sharp angular blocks and fragments of flint and cherty limestone. Little wonder that, overladen and fatigued by the long distance already covered, the camels died in great numbers on this last stretch of road. Along most

desert routes the dried bones of camels are of fairly frequent occurrence, but on the Derb el Arbaîn, between Kharga and Assiut, the skeletons of these poor beasts are met with in groups of tens and twenties, and must number hundreds and thousands. In many instances the skeleton still lies undisturbed, in the position assumed by the luckless animal in its death agony, the long neck curved back by muscular contraction so that the skull lies in contact with the spine. When one sees these remains, half buried in the sand, the bones bleached snow-white by a pitiless sun, with still adhering fragments of skin and muscle dried hard as adamant, one cannot but feel pity for those patient 'ships of the desert,' wrecked almost within sight of port.

Cailliaud, in 1817, observed the arrival at Assiut of a large caravan from Darfur, consisting of 16,000 individuals. It included 6,000 slaves—men, women, and children. He remarks: "They had been two months travelling in the deserts, in the most intense heat of the year; meagre, exhausted, and the aspect of death on their countenances, the spectacle strongly excited compassion."

The actual width of the plateau varies from 120 kilometres between Abu Sighawâl and the scarp above Waled Hallaf, to 200 kilometres between Beris and Esna. The maximum elevation above sea-level is about 550 metres on the latitude of Esna, and on the whole the plateau has a fairly general slope to the north. As already mentioned, several distinct types of country, depending on the

nature of the rocks constituting the surface strata, are met with. Smooth, hard, level plains, formed of a superficial layer of weathered limestone covered by a brown veneer of insoluble flint and cherty fragments, alternate with bare rugged rock desert of hummocky limestone. The sombre level or gently undulating flint-covered plains, frequently spoken of as 'serir' by the Arabs, have ideal surfaces for travelling; the light-coloured hummocky country, often called 'kharafish,' is in its most developed form made up of innumerable elongated hillocks, every portion of the exposed rock-surfaces being deeply scored; the furrows are separated by upstanding edges, often so sharp and knife-like as to be capable of injuring the feet of man and beast. The hillocks are separated by deep troughs half buried in drift-sand, all lying parallel, in the direction of the prevailing winds, so that progress in a latitudinal direction through this type of desert is a slow and tedious undertaking. Both types of country are equally desolate and barren, scrub of any description being of the rarest occurrence, except after local thunderstorms. Another type of country, to which we have already briefly alluded, is the curious desert-surface called El Botîkh (the water-melons), which results from the weathering of certain bands of the Lower Eocene formation containing numbers of large globular concretions; these, it may be mentioned, often lie so thickly strewn on the surface as to actually obstruct the passing caravan.

Kharga is connected with the oasis of Dakhla to the west by two roads, the lower and more southerly, known as the Derb el Ghubbâri, being the one most frequently used. This road, by taking a wide sweep to the south, avoids the intervening plateau altogether, so that the fatiguing ascent and descent are avoided. After leaving Kharga village the route leads past a group of wells, known as Ain Khenâfish, distant some 6 kilometres; thence it lies over wide-stretching plains of sandstone, leading up to the more broken country formed by the foot-hills of the towering plateau, which is always plainly visible on the north side of the road. The distance to Tenîda, the most easterly of the Dakhla villages, is 143 kilometres by the Derb el Ghubbâri.

The alternative route by way of Ain Amûr is appreciably shorter, though, owing to the extra time involved in negotiating the steep passes to and from the plateau, there is little saving in time when travelling with a heavily-laden caravan. Compared with the lower road, however, this route is much more interesting and picturesque, and the presence of water at Ain Amûr, about half-way between the two oases, is a distinct advantage. The road from Kharga village lies over a broad plain, whose only features are occasional conical hills of dark ferruginous sandstone. It follows a W.N.W. direction, heading for the great indentation to the west of the Jebel Tarif range. After getting well into the recess, but when still some

15 kilometres from its head, the road turns abruptly to the south, and winds its way up an escarpment littered with huge blocks of tufaceous limestone. Perched near the summit of the cliffs stands the solitary palm which marks the site of the water-hole, in the immediate neighbourhood of which grows a fair amount of prickly scrub. The remains of mud-brick buildings and a stone temple show that this place was formerly inhabited, and of some importance.

The ascent to the plateau from Ain Amûr needs care with laden camels. The road proceeds up a narrow defile, the actual track being very rough, and so confined that in places the packs are liable to be dragged off by the rocks on either side. Once on the plateau the going becomes first rate, the freedom of the surface from blown sand being very noticeable. This is due to the isolation of this portion of the plateau-massif, which is cut off from the main mass to the north by the deep recess, and is bounded by a low-lying plain to the south. After a distance of 33 kilometres has been traversed the road descends into a narrow valley opening on to the low country to the south, and proceeds in a westerly direction to Tenîda. The distance from Kharga to Tenîda by this route is 128 kilometres.

It is possible on leaving Ain Amûr to cross to the top of the indentation, and thence to proceed across the plateau almost due west, striking the road from Assiut, known as the Derb el Tawîl, at the top of the pass 25 kilometres from the village

of Belat. There is, however, no track, and the surface is covered with parallel north and south ridges of rock, the crossing of which is extremely wearisome. Both near the head of the Ain Amûr recess and in the extreme north-west corner of the oasis very old tracks trending in westerly and north-westerly directions are observable, and although unused at the present day, these may mark the positions of formerly frequented routes leading to the oasis of Farafra. At the present time that oasis is not in direct communication with Kharga, the routes used being from Manfalut in the Nile Valley, from Qasr Dakhl in the oasis of Dakhla, and from Ain el Hais in Baharia.

Before leaving the subject of roads we must briefly refer to the route taken by the railway. The line, which has a gauge of 75 centimetres, was built by the Corporation of Western Egypt, Limited, to develop their concessions in the oasis. It commences at Mouaslet el Kharga, a new station on the Egyptian State Railway near Farshut, and crosses to the border of the desert, a few kilometres distant, by way of one of the embankments separating two of the great irrigation basins of Upper Egypt. At the edge of the desert is the station of El Qara, the point of departure for the oasis. After skirting the margin of the Nile Valley cultivation for a short distance it heads straight for the Wadi Samhûd, by means of which the plateau is gained without encountering any very heavy gradients. From the top of the Wadi Samhûd

THE RAILWAY DESCENDING INTO THE OASIS.

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the line follows the Abu Sighawâl road for about 40 kilometres, after which it diverges a few degrees and proceeds to El Tundaba, the shaft already described, 92 kilometres from Mouaslet el Kharga. From El Tundaba the railway follows more or less closely the cross-track, sometimes called the Derb el Refûf, which joins the Sohag road at El Shugera, and, entering the depression by the Refûf pass, follows down the gully, and thence across the plain to the station of Meheriq. From Meheriq it proceeds nearly due south to the Corporation's headquarters, and thence on to its present terminus a few kilometres from Kharga village.

My friend Ball lays great stress on the tortuous nature of the roads between the oasis and the valley, and recommends the scientific traveller to steer an independent course. But after traversing the majority of the main caravan roads, and with a fairly intimate knowledge of the characters of the intervening areas, I must say that, in my opinion, it would be difficult to better them. These roads were not laid out yesterday, but result from the accumulated experience of centuries. The original tracks may have been tortuous enough, but they have become straightened out by the cutting off of corners here and there, until at the present day the roads fulfil the three most important objects in view—the ascent and descent to and from the plateau at the points offering the easiest gradients, and the crossing of the plateau itself as directly as

possible over the smoothest and most level ground available. The roads give a wide berth to the outcrops of rough limestone, and anyone who has done much cross-country travelling in the Libyan Desert will appreciate their doing so.

Nor can I concur with the same author in his opinion that the Bedawin of this side of the Nile have a poor knowledge of their beloved desert. It is certainly true that the Arab does, for very good reasons, prefer to travel on the beaten tracks rather than undertake exploratory missions as the crow flies, his main object being to get to his destination as rapidly and easily as possible. If by chance, however, rain should fall on any portion of the desert, the Arab will very shortly be found there, taking full advantage of what Allah has provided in the way of free grazing for his herds. My own experience has been that the Arabs have among them a fair proportion of men with an extensive knowledge of the western desert, and I have frequently been struck by their wonderful knowledge of the roads and the facility with which many of them can follow the tracks on the blackest of nights, as even in broad daylight the landmarks which a European could recognize on second acquaintance are few and far between. The average Bedawi cannot be said to have exceptionally long sight, but he is frequently possessed of a wonderful sense of direction.

Travellers in the Egyptian deserts are apt to underrate the intelligence of the Bedawin, owing to the fact that they unconsciously form their im-

pressions from the miserable specimens of humanity so frequently sent out by the actual owners of the camels to act as drivers and attendants to a hired caravan. In such caravans there is seldom more than one man who knows the particular roads to be followed; the rest are wretched underfed creatures, generally half-breeds, who for a mere pittance tramp day after day, uncomplainingly and shoeless, alongside the caravan. They are much to be pitied, and it would be as unreasonable to expect them to have any special knowledge of the desert as it would be to look for information regarding, say, the mountains of Wales among the poorer classes of a Welsh town.

I do not wish to minimize the value of cross-country traverses carried out with special scientific objects; they are, indeed, often necessary for topographical and geological purposes. I would, however, warn the enthusiastic tyro that, in the Libyan Desert, travelling as the crow flies is not always so simple and glorious an affair as it may seem when planning expeditions from a comfortable arm-chair; and if his object is to get a short cut he will probably have reason to bitterly regret the moment he left the beaten track. I have in mind more than one instance where mistakes of this kind have been made, mistakes which might easily have led to disastrous consequences. In long cross-country traverses an error in steering of only two or three degrees will in a few marches throw a caravan many kilometres out of its course, and guiding camels

over rough country by compass is by no means an easy undertaking. Moreover, easily distinguishable landmarks are rare, and the desert plains over wide areas maintain remarkably persistent characteristics. Quite recently I recollect an Englishman, whose Arab attendant had become suddenly incapacitated by an attack of fever or sunstroke, getting hopelessly astray between the edge of the plateau overlooking the oasis and rail-head, which was then only 20 or 30 kilometres distant, in consequence of his missing the bifurcation of the road at El Shugera, and proceeding, owing to this mistake, along the route leading to Sohag.

Along the caravan roads the sharp fragments of rock have been stamped underground or kicked to one side, but elsewhere they usually litter the surface, and are very trying to camels, whose pads, though soft and yielding, are easily worn by much travelling over rough country. This has more than once been painfully impressed upon me by the antics of my own riding camel, whose mode of progression at such times resembled more the dance of a fanatic on red-hot coals than the ordinary gait of a well-bred 'hegîn.' Over some areas, however, one can travel in a straight line without let or hindrance, and in such cases it is only necessary to lay out the course correctly in the first instance, and to have the courage of one's opinion to stick to that course until the destination is reached. One must not heed the remonstrances of the less sporting members of the expedition, who will lose no oppor-

tunity of predicting disaster, and in this respect the new chum fresh out from home is generally the greatest offender.

One of the longest cross-country traverses I myself have undertaken in the Libyan Desert was from Farafra Oasis to Assiut. The only road between that oasis and the Nile Valley strikes the latter near El Qusîya, midway between the towns Manfalut and Derut, so that travellers who wish to make Assiut have an additional day's march southwards alongside the margin of the cultivated lands. On gaining the summit of the pass above Bir Murr, on the east side of the Farafra depression, I abandoned the road and set a course direct for Assiut, steering and plotting my route by compass and plane-table, the distance being reckoned by measuring-wheel. The most satisfactory method of procedure on desert traverses is to lay out a line, representing the correct bearing of the destination, along the centre of the longer axis of the plane-table, and then to steer to any well-marked object lying on either side, but within reasonable distance, of the proper course. At every station the exact position reached is plotted, and steps are taken, when selecting the next point on which to march, to converge towards the correct course marked down the centre of the table.

On this particular traverse I was unaccompanied by Europeans or Bedawin, my camel drivers being fellahin from the Nile Valley. The surface proved excellent going, and the Abu Mohariq belt of dunes,

190 kilometres from Qasr Farafra, was crossed without trouble. Eight days after leaving Farafra village we struck the escarpment of the Nile Valley, having covered nearly 300 kilometres, and found we were marching on a point only very little to one side of the town of Assiut. From this traverse it was possible to calculate the longitude of Farafra with fair accuracy.

The normal rate of travelling of camels carrying ordinary loads weighing from three to four hundredweight is 4 kilometres, or about $2\frac{1}{2}$ miles, an hour, ten hours being the usual day's march of caravans when accompanied by Europeans. The native caravans, carrying dates and other heavy merchandise, usually traverse the plateau in three days and nights, doing stages of 60 to 70 kilometres at a stretch. By travelling very light with trotting camels I have, on more than one occasion, crossed from the oasis to the valley in between thirty and thirty-five hours, doing from 180 to 190 kilometres in two stages of about twelve hours each, with one stop only of nine or ten hours.

CHAPTER IV

TOPOGRAPHY AND GEOLOGY

Dimensions of the Oasis-Depression—Jebel Têr, Jebel Tarif, and other Hills within the Depression—Aspect of the Oasis from the surrounding Escarpments—Geological Sequence —Nature and Thickness of the Strata—Geological History of the Oasis—Formation of the Depression—Difference of Level of Strata on either side of the Depression—The Great Longitudinal Flexure—Height of the Floor compared with Sea-Level—Altitudes.

KHARGA, the eastern of the two southern oases, is a depression lying with its longer axis north and south, mostly bounded by steep and lofty escarpments, but open to the south and south-west, on which sides the country rises gradually from the floor of the oasis. The extreme length of the depression, from the northern wall to Jebel Abu Bayan, which for convenience may be regarded as the southern limit of the oasis proper, is 185 kilometres, or 115 miles. The general trend of the eastern escarpment is nearly due north and south, but that on the west is very irregular, while to the south and south-west there is no definite boundary. The breadth of the depression may therefore be said to vary from 20 to 80 kilometres.

The ranges of Jebel Têr and Jebel Tarif form isolated hill-massifs in the centre of the northern part of the depression, while Jebel Ghennîma and Jebel Um el Ghennaim are conspicuous outliers of the plateau on the east side. With the exception of these, the floor is destitute of anything beyond comparatively insignificant eminences, unless we include the small range of hills known as the Gorn el Gennâh, to the south-east of the village of Gennâh, which is noticeable more on account of its sharply-defined peaks than of its general elevation above the surrounding country. Referring to the two conspicuous peaks, Ghennîma and Um el Ghennaim—Jimmy and Jemima, as I have heard them dubbed—reminds me that on the Survey and on some of the older maps the names are reversed. I have questioned a number of natives regarding the names of these hills, and have invariably been informed that Ghennîma is the more northerly of the two.

The villages, wells, and cultivated lands lie within a north and south band, occupying the lowest portion of the floor, and following the general trend of the depression. They are, however, broken up by a broad area of barren desert into two distinct north and south groups, of which Kharga and Beris villages are the chief centres respectively. A description of these is reserved for a later chapter.

When a traveller, after crossing the broad monotonous plateau, at length reaches the scarp or wall of the oasis, and sees spread out before him a vast

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depression, stretching in some directions as far as the eye can reach, in others to the opposite bounding walls dimly discernible on the far horizon, he can hardly refrain from speculating as to the causes which have given rise to such huge hollows in the plateau. When he descends to the cultivated portions of the floor of the depression, and sees those numerous bubbling springs, which alone make life possible in the midst of this otherwise deadly wilderness, his second inquiry is as to whence comes such abundance of water in one of the most arid regions in the world. These questions are worth asking, and, so far as the present state of our knowledge permits, it will be my endeavour to answer them. I propose, therefore, to briefly place on record such information and data as I have been able to gain, but as both topography and water-supply are intimately connected with the geology of the district, it will be necessary at the outset to devote a few pages to a consideration of the latter.

The geological deposits found in the oasis of Kharga are tabulated on the following page, commencing with those most recently formed. The succession, as shown in the table, is that which obtains in the northern part of the depression, but as far as is known the same stages occur throughout the oasis, and do not vary either in thickness or in lithological characters to any great extent. Over large areas the lower-lying parts of the oasis-floor are formed of those beds which we have designated the Surface-water Sandstone, though in

Geological System.		Stage.	Thickness in Metres.
Recent and Pleistocene	... ...	Sand-Dunes, Spring Deposits (modern), Lacustrine Sands and Clays, Calcareous Tufa	Very variable
Lower Eocene	Lower Libyan	Plateau Limestone	115
	Passage Beds	Esna Shales and Marls	55
Upper Cretaceous	Danian	White Chalk, Ash-grey Shales	70
		Exogyra Beds	30
	Campanian (Nubian Series)	Phosphate Beds	70
		Purple Shales	50
		Surface-water Sandstone	45
		Impermeable Grey Shales	75
		Artesian-water Sandstone	120
	Total		630

places the still older underlying grey shales are exposed. The purple or red shales generally form the rising ground towards the escarpments, at the base of which are usually found the phosphatic beds, with hard, pronounced bands made up of fish-remains and phosphatic nodules. Above come the Exogyra Beds, with thick bands of limestone almost entirely composed of large oyster-shells. Rising up above these is the generally well-marked cliff of grey shales, capped by a snow-white chalk of much the same age geologically as the well-known chalk of the South of England. The summit of the chalk frequently forms a separate plateau, subsidiary to the high desert tableland, and separated from it by the cliffs formed of the massive Eocene limestones.

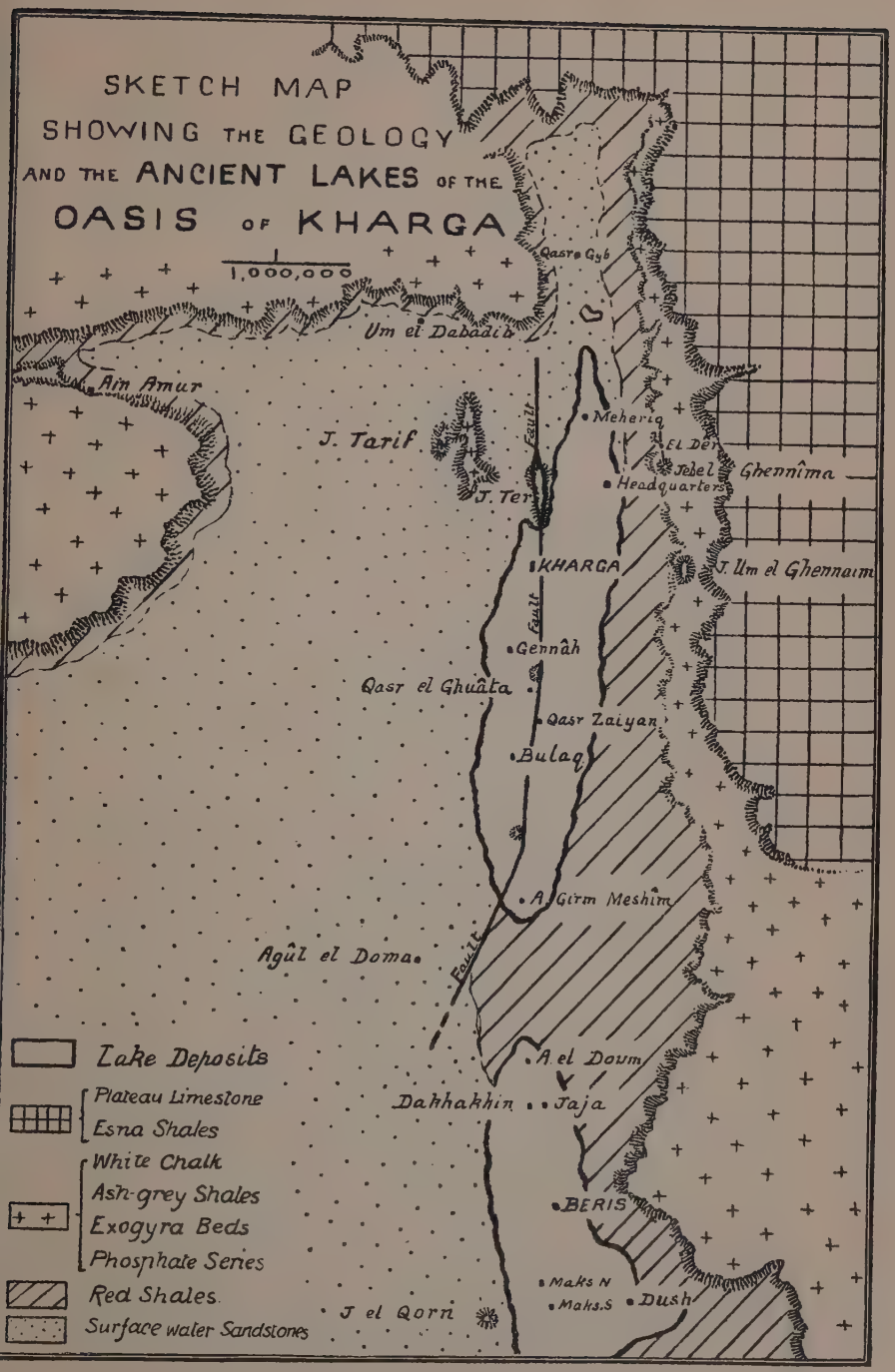
The total thickness of the exposed strata is about 435 metres, a figure obtained by actual measure-

ment. Numerous borings show the thickness of the unexposed underlying Impermeable Grey Shales to be 75 metres, and the deepest borings yet made have pierced the still lower Artesian-water Sandstone to a depth of 120 metres, making a grand total of known deposits of 630 metres, or 2,067 feet. The depth to which the water-bearing sandstone extends is at present a matter of speculation ; the point is of great importance in connection with the water-supply, though up to the present no borings of sufficient depth have been made to determine its thickness, nature, and relation to the underlying igneous rocks.

With the exception of a few isolated bosses of eruptive rock in the desert to the south of the oasis —indications of the granitic foundation which probably underlies the entire area—the geological deposits of the oasis-depression, and of the surrounding escarpments and plateaux, are entirely of sedimentary origin, that is to say, they were laid down on the shores and beds of pre-existing seas and inland lakes. The sand-dunes are, of course, an exception, having been deposited by the wind on the surface of the land. Although, geologically speaking, the oldest group of sediments with which we have to deal belongs to the later chapters of the earth's history, many hundreds of thousands of years have elapsed since the sandstones and shales, now forming and underlying the floor of the oasis, were accumulated on the bed of a vast inland lake. This sheet of comparatively fresh water was then

invaded by the sea, which held sway in the region while the whole of the series of sediments, now exposed in the cliffs of the oasis and some 350 metres in thickness, were being laid down. In Middle Eocene times the sea commenced to retreat to the north, and the area under description became dry land with a continually receding shore-line. Since that time the forces of denudation have constantly been at work lowering the general surface of the plateau and excavating those depressions in which alone at the present day man is able to exist.

The Egyptian oases are deep and extensive depressions or hollows cut down nearly to sea-level through the generally horizontal rocks forming the Libyan Desert plateaux, and appear to owe their origin in great measure to the differential effects of subaërial denudation acting on rock-masses of varying hardness and composition. The surface-features or configuration of almost any land which has long been exposed to the powerful forces of erosion are more or less intimately dependent on the structure and lithological characters of the underlying rocks. On relative hardness, more than on anything else perhaps, depend the ultimate positions of mountains, hills, and plateaux on the one hand, of valleys, plains, and depressions on the other. Variation in the original conditions of deposition, at the time when the rocks now forming the Libyan Desert were laid down on the floor of the sea, has resulted in a preponderant development in some areas of soft clayey or sandy rocks (as com-



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pared with the hard limestones), and subsequent earth-movements have raised these beds more in some districts than in others. The result has been that wherever, during the gradual denudation to which the country since its elevation has been subjected, these soft deposits have become exposed on the surface, weathering has proceeded at a greatly increased rate, and eventually produced deep and broad depressions separated by high limestone tablelands.

But for the presence of comparatively soft formations such as the Esna Shales, the Exogyra Beds, and the Nubian Sandstone, coupled with the facts that they have an unequal development in different areas, and occur at a greater elevation in some localities than in others, the great depressions of the Libyan Desert would not have come into existence, or at any rate would have been of comparatively little importance in the configuration of the country.

The oases are true depressions, completely or partially surrounded by high escarpments. The oasis of Baharia, for instance, is on all sides hemmed in by cliffs; on the other hand, Dakhla and Kharga are open to the south, but as the ground in that direction rises considerably, they, too, cannot be regarded as other than true depressions. We have no definite grounds for considering that the erosion of these depressions can have been the work of previously existing rivers, and there is no evidence to warrant us in assuming them to have been formed by local subsidence of portions of the earth's crust.

What, then, were the agents of denudation and transportation which operated in the formation of these great depressions? Under the existing arid conditions the surface rocks, unprotected by vegetation, are rapidly disintegrated or weathered as the result of the great diurnal variations of temperature to which they are subjected (insolation). The weathered material, however, does not accumulate and form a protective soil-cap, but is carried away by the wind (deflation), the heavier siliceous grains effecting an immense amount of abrasion of the exposed rock-surfaces over which they are swept. Changes of temperature, sand, and wind are, indeed, the chief agents of erosion and transportation at the present day, and, given a sufficiency of time and a continuance of favourable conditions, we can confidently admit the combination to be capable of effecting a vast amount of earth-sculpture. But the formation, in this way, of huge hollows 300 to 400 metres deep, and the removal of material amounting to hundreds of cubic kilometres, would necessitate the assumption that the present rigorous desert conditions have obtained for a very considerable period.

Taking all the available evidence of which we are cognizant into consideration, we do not feel justified in assuming this to have been the case, especially when we recollect the frequent presence on the escarpments of thick deposits of calcareous tufa, which it is evident must have been laid down after the depression had been carved out to a con-

siderable depth. These tufas are almost certainly of Pleistocene age, though whether they date from the early or late part of that period has not been determined. In some localities they occur as thick, horizontally-stratified beds, and were evidently deposited on the bottoms of lakes; in other places they appear as fan-like cakes spread over the face of the cliff, and may have been formed by springs situated near the summits of the escarpments. The tufas frequently contain large numbers of fresh-water shells and an abundance of fossil vegetation, and, from the presence of casts of the leaves of such trees as the oak, one is led to refer the deposit to the more humid period which preceded the incoming of the modern desert conditions.

Although the evidence met with in the field is altogether against the idea that portions of the plateau have been bodily let down by subsidence, there are good reasons for believing that tectonic movements have played an important part in deciding the general shape of the oases-depressions. For instance, there is considerable parallelism between the general trend of the Baharia depression and the folds which pass through that region. As a result of those folds, it is not improbable that the hard limestone beds were to some extent broken up, and the soft underlying clays and sandstones raised as compared with their position on either side of the folded belt. In Kharga, similarly, the main axis of the depression is, as we shall show, distinctly parallel to the great north and south line of flexure, and

there is little doubt that a close connection exists between the two. On the other hand, I know of no folding in the case of Farafra, which appears to owe its existence solely to the fact that there was in that region an unusual development of shales at the base of the Eocene nummulitic limestones. Of the four Egyptian oases, perhaps Dakhla is the one most easily accounted for, as this depression may be regarded as simply due to the general northerly dip of the sedimentary formations, and the gradual weathering back (northwards) of the great argillaceous series (Exogyra Beds) capped by the White Chalk. The original limits of the latter may, indeed, never have been very far to the south.*

While all sedimentary strata—such as the limestones, sandstones, clays, and shales with which we are now dealing—were originally deposited either quite horizontally or inclined at only a very low angle, it by no means follows that this horizontality is maintained when the strata are elevated into dry

* Since writing the above, I have read with much interest a paper on the South-West Desert of Egypt, in which my friend and former colleague, Dr. W. F. Hume, in a discussion of the formation of the oases-depressions, refers to the importance of soft and hard strata, and to the action of folding in exposing the former to the agents of denudation. This is striking confirmation of the views promulgated by me since my first acquaintance with the oases many years ago. Of great interest and value, being new, is the suggestion that the topography of the southern oases and surrounding desert may be, to a considerable extent, due to denudation acting on the country as it was in process of being elevated from the sea in which the deposits forming it had been laid down.

land. Over the Libyan Desert as a whole the successive sedimentary formations dip steadily northwards, but at a very small inclination. This results in every stage having a wide outcrop, so much so that, if it were not for the cliff-sections of the Nile Valley and the oases-depressions, we should have to travel immense distances to obtain any idea of the true succession of rocks. This general horizontality of strata appears at first sight to be well maintained in the oasis of Kharga, as whether we stand on the summit of the eastern escarpment, on top of the great central hill-massif of Jebel Tarif, or on the plateau above Ain Amûr, we see everywhere horizontally-disposed beds of limestone forming the plateaux and upper portions of the cliffs, with parallel bands of sandstone, shale, and chalk outcropping on the slopes below.

A closer examination, however, will show that there is in reality a difference in level of more than 200 metres between the same beds on either side of the oasis; for the beds capping Jebel Tarif belong to the White Chalk of the Cretaceous system, and are therefore very much older than those of Eocene age forming the eastern plateau (see map and section). This great difference in vertical position is due partly to a steady dip from west to east, partly to a remarkable longitudinal flexure running north and south through the centre of the depression, and partly to a gentle fold near the base of the eastern escarpment. Along the actual line of flexure, which passes through Jebel Têr, Jebel

Tarwan, Nadûra, Gorn el Gennâh, and Gertuma (S.S.E. of Bulaq), the different rock-stages are folded and fractured to a remarkable degree. Throughout the greater part of its course the flexure approximates to the type of disturbance known as a simple monocline, but in places, as in Jebel Têr, it passes into a syncline bounded by nearly vertical faults; while in others the beds are bent into almost symmetrical basins or centroclinal folds, typical examples of these structures being met with at points 6 kilometres south of Kharga village and 2 kilometres south-west of Qasr Zaiyan.

The importance of this line of folding and faulting must not be lost sight of, as although the dislocations produced are only actually visible in the case of the exposed upper beds of the oasis sequence, the earth-movements to which it owes its origin have had similar disturbing effects on the underlying and hidden water-bearing strata. Ball reported that the most striking evidence of faulting was between Jebel Têr and Jebel Tarif, and showed the fault as running for a short distance in a N.N.E. and S.S.W. direction, but, as already mentioned, the line of disturbance is coincident with the longer axis of the former range, so that the majority of the wells are on the west or upthrow side of the fault. The effects of this faulting and folding on the underground water-supply will be further alluded to in a later chapter.

In the early summer of this year (1908) I followed the line of flexure southwards in order to determine

whether it continued throughout the oasis. As far as the small eminence of Gala, about 10 kilometres south of Bulaq, it ran in an almost straight line, but south of that point its course took a distinct bend to the west, so that the fold was very soon lost in the great belt of sand-dunes. Beyond this point its continuation could, however, be inferred by occasional exposures of steeply inclined sandstones, the most southerly point to which it was actually traced being in latitude 24° 55′ N., about 15 kilometres S.S.W. of Ain Girm Meshîm.

Before concluding our remarks on the geology of the oasis we must not omit to call attention to the beautiful and varied fossil remains which are almost everywhere to be met with in the calcareous beds of the hills and escarpments. It is, of course, by the study and comparison of these organic remains that geologists are enabled to determine the relative ages of the beds in which they occur, and thus to correlate them with the rocks of other countries. The lower argillaceous and arenaceous deposits of the oasis are comparatively unfossiliferous.

From any of the points of vantage, such as are afforded by the higher hills within the depression, the general level of the floor of the oasis does not appear to vary to any great extent, but actual levelling shows that this is not in reality the case; and it is this variation of absolute level which is the primary cause of the very varying volumes of water yielded by the artesian wells in the different districts.

The average height of the centre of the depression in the neighbourhood of the village of Kharga is approximately the same as that of the Nile Valley plain in the latitude of Farshut.

Ball, by comparison of a series of aneroid barometer readings with the barometric records for the same period at the Cairo observatory, deduced the value of a point near Kharga village as 86 metres above sea-level, and used this as his datum in calculating the levels of other parts of the oasis. Previous aneroid determinations of the same point had been made by Cailliaud (104 and 118 metres) and by Jordan (68 metres). But even when the greatest possible precautions are exercised, aneroid determinations, especially when made with a single instrument, are necessarily unreliable, and still more so when used for calculating the levels of different points on a plain having only comparatively slight irregularities of surface.

Utilizing the figure obtained by the railway surveyors for a point near the termination of the line, we get values of 58 and 60 metres above sea-level for Kharga village and Bore No. 1 at headquarters respectively, and a bench-mark at the latter place, having a value of 60·1, is used as the datum from which all the heights given in this book are calculated. Unfortunately it is not possible, owing to the lack of sufficient check-levels, to state the limit of probable error, and it must therefore be understood that the value of our datum, which in the meantime may be accepted as the best obtainable, is subject to future revision.

From this central point (Bore No. 1) lines of levels have recently been carried in every direction by Mr. F. E. Apted and myself, with the result that it has been shown that the general level of the floor of the oasis rises steadily to the north and falls to the south. These levels have in all cases been checked, and may, using the datum mentioned, be accepted as fairly reliable, the closing errors on the different loops being generally within a very few centimetres. The altitudes of a few reference points in each district are given here.

District.	Point.	Altitude.
Headquarters	Bore No. 1	60·1
„ „	Bore No. 44	53·1
Kharga	Bir Ain el Gôs	70·2
„	Ain el Sabbagh	56·9
„	Ain Zaaf	87·7
„	Temple of Hibis (floor)	75·0
Meheriq...	Bir Qattara	56·6
„	Ain Mahmud	64·8
„	Ain el Burg	69·6
„	Ain el Qasr	76·0
„	Ain el Ghazâl	84·6
South of headquarters ...	Ain Harrân	43·5
„ „ „ ...	Ain Ali Morad	33·0
„ „ „ ...	Ain Bellal	28·4
„ „ „ ...	Ain el Tawîl	19·7
Gennâh	Ain Estakherab	71·3
„	Ain Magarin	74·6
„	Ain el Ghuâta (north)	48·2
„	Ain Zaiyan	41·6
„	Qasr Zaiyan	20·7
El Dêr	Bore No. 22	92·3

The Government Survey maps show a portion of the oasis floor as lying below sea-level, the differ-

ence of height between the Kharga village datum and a point just south of Qasr Zaiyan being given as 104 metres. Detailed surveying shows that this estimate is excessive, the true difference being about 37 metres only. Although no actual reading has yet been obtained below sea-level—the lowest being +2·6 metres at a point $3\frac{1}{2}$ kilometres north-east of the northern end of the Gorn el Gennâh, or nearly midway between that hill and Ain el Tawîl—it is evident that in this district the floor is only very slightly higher than the sea, and it may be that at one or two points its level is actually lower.

South of Qasr Zaiyan no revision of previous levels has as yet been made. According to Ball's figures, the village of Beris is approximately 10 metres lower than Kharga.

While discussing the subject of levels it may be useful to note the relative heights of the escarpments and hills within the oasis. The edge of the eastern plateau varies from 350 to 400 metres above sea-level, while the plateau to the north of Um el Dabâdib has a general level of about 400 metres. Jebel Tarif appears to be very slightly higher, while the highest peak on Jebel Têr is not much more than 300 metres. The altitudes of these points with reference to the village were mostly determined by Ball by trigonometric observations with an eight-inch theodolite, and can therefore be relied on as being accurate.

CHAPTER V

THE NORTHERN VILLAGES

Population—Relation of Population to Water-Supply—Trade in Dates—Imports—Taxation on Date-Palms and Wells—Measurement of Wells—Revenue derived from the Oasis—Origin of Inhabitants—Kharga Village—Industries—Ancient and Modern Wells—Meheriq Village—Troubles with Sand—Migration of Villagers—Ain el Tawîl and other Hamlets—Gennâh Village—Famous Wells—Ain Estakherab—Ochreous Waters of certain Wells—Ain el Ghuâta—Bulaq Village—Doum-Palms—Tomb of Sheikh Khalid Ibn el Walîd.

In point of population Kharga ranks second of the four great oases of the Libyan Desert. In 1897 the inhabitants numbered 7,856, and ten years later had increased to 8,348. The 1907 census showed the male to be slightly in excess of the female population, a result entirely owing to the preponderance of men in the northern part of the oasis. The present distribution of the inhabitants, according to the last census, is shown in the table on the following page.

In the oases of the Libyan Desert there is a very close connection between population and water-supply. No water is intentionally allowed to run to waste, every drop being utilized to raise

	Male.	Female.	Total.
Kharga District	2,819	2,503	5,322
Gennâh District	207	237	444
Bulaq District	487	529	1,016
Beris District	767	799	1,566
Total	4,280	4,068	8,348

the crops of rice, dates, barley, and wheat, which form the staple food-supplies of the inhabitants. Cut off by a waterless desert, these people have little intercourse with the outside world, except for a few weeks in the early winter months, when they dispose of their surplus date-crop to the Bedawin traders who cross the desert with droves of camels from the Nile Valley. The dates are usually paid for in cash, ready-money being required in order to meet the annual taxes levied by the Egyptian Government. Practically the only food-stuffs imported consist of such commodities as tea, coffee, and sugar, which are used sparingly, and regarded as luxuries even by the better classes.

It is evident, therefore, that the inhabitants rely almost entirely for subsistence on the products they are able to raise by their own toil and industry. Owing to there being no rainfall, the acreage of land which can be put under crops depends absolutely on the amount of water available for irrigation by wells. The total yield of the latter has, we know, fluctuated to a considerable

extent at different times, and one may surmise that, could figures be obtained giving the number of inhabitants and the volume of the water-supply for different periods during the last 5,000 years, a remarkably constant ratio would be observable between the two.

Taxes are levied by the Egyptian Government on both date-trees and wells. Over 60,000 adult palms exist in the oasis, each one being subject to a yearly tax of $1\frac{1}{2}$ piastres (about $3\frac{1}{2}$d.). The output or yield of a well is, for purposes of taxation, determined in a somewhat rough-and-ready manner by a method which appears to have been in use for a number of generations. Whenever a new bore is completed, or an old well requires remeasurement, all the most influential personages in the oasis, headed by the Omda or chief of Kharga village, armed with a number of primitive appliances, solemnly proceed to the spot.

After first ascertaining that the well has not been temporarily blocked by interested persons—even here in the remote interior of the desert there is an inherent objection to the paying of taxes—the bed and sides of the water-channel are made as smooth as possible for a distance of five or ten paces below the mouth of the well, so that the water flows away with an even ripple. A small pointed stick is now inserted in the centre of the bed of the stream, in such a way that the top of the peg is exactly flush with the surface of the water. Then the Omda, hitching up his flowing robes, steps into the stream,

and, selecting a gauge of suitable dimensions, fixes it firmly in the bed of the channel, in such a position that the whole of the flow passes freely through, without raising or lowering the surface of the stream above, as indicated by the peg. The interior of the gauge, a roughly-made wooden frame, is intended to be a definite number of centimetres in length, but in many of those used there is a small error. As soon as the stream flows evenly over the gauge or weir, without its surface-level being altered, the depth of water is measured on a scale. The latter is wetted and plunged into a heap of dry sand before being used, the depth of water being indicated by that portion of the scale from which the sand has been removed by the immersion. Observations are made at both ends of the weir to insure any error due to want of horizontality of the frame being detected.

The actual discharge is reckoned in 'qirats' and eighths of a qirat (tumns), a qirat being a water-section of 64 square centimetres. For example, if the depth of water passing over a gauge having an internal length of 40 centimetres was found to be 8 centimetres, the water-section would amount to $40 \times 8 = 320$ square centimetres, which would be reckoned as a discharge of 5 qirats.

The Omda and his attendants carry out the operations with the utmost care and solemnity, and have the most touching faith in the accuracy of their results. Apart, however, from errors in the gauges and scales used, and from the want of

provision of a free fall on the downstream side of the weir, the fact that the velocity of the stream is entirely left out of account is sufficient to give the qirat a very variable value, low for small and high for large streams, the result being that the small wells are being taxed at about 50 per cent. higher rates than the large ones. In order to ascertain the average value of the qirat for streams of different size, I arranged with Mr. Patterson, who at the time was the Government Representative in Kharga, to send the Omda to headquarters and instruct him to measure a number of new bores belonging to the Corporation of Western Egypt, as these bores, being cased and provided with proper outlet valves, lend themselves to exact measurement better than the majority of the native-owned wells. The Omda employed the ordinary local native method just described, while I, using a tank of known capacity and a reliable stop-watch, made direct measurements immediately afterwards. The results obtained show that below 2 the qirat has a value of 22 gallons a minute; from 2 to 4 of 26 gallons a minute; and from 5 to 6 of 38 gallons a minute.

The annual tax levied on the water amounts to 50 piastres (about 10s. 3d.) per qirat. If the average value of the qirat be taken at 25 gallons per minute, the tax works out at approximately 1s. for every 6,000 cubic metres of water. Looked at from another point of view, it may be considered that the tax amounts to about 1s. 6d. an acre, as with every qirat of water the native cultivator in

the oasis will annually raise about two acres of rice and five of wheat or barley.

The total revenue derived by the Government from the oasis, by taxes on date-palms and water, amounts to a little over £1,000 per annum.

My old friend Sheikh Mustapha, who for more than twelve years has been Omda of Kharga village, was very anxious to know the results of the comparative measurements made on the bores. He professed himself as surprised at the difference in the results, but emphatically refused to entertain the possibility of there being any error in his measurements, made by so old-established a method. Although he was far too polite to so express himself in words, I felt that the old gentleman had the utmost contempt for my method of well measurement.

With the exception of the Dakhla peasants, the inhabitants of the oases differ entirely from the fellahin of the Nile Valley. According to Brugsch, the original inhabitants were Libyan (Berber) tribes, but after annexation to Egypt, there was considerable immigration from Nubia and other parts of the Nile Valley. Nevertheless, in the oasis of Kharga the physiognomic type of the Berber race is still predominant.

El Kharga, the chief village of the oasis, containing about 4,500 inhabitants, is situated in a broad belt of cultivated lands and palm-groves running centrally down the depression from the southern extremity of Jebel Têr. The village

consists of a picturesque compact conglomeration of houses, built of sun-dried bricks, and of every shape and size. The streets meander in a very remarkable manner, and are to a large extent in partial or total darkness, owing to their being for the most part roofed over and covered by upper storeys. Without the aid of a guide it is almost impossible to find one's way through the intricacies of the underground passages, though no fears need be entertained on the score of being in any way molested, the inhabitants being most peaceably inclined. In some parts of the village the streets are actually cut through the solid rock. They are generally clean and cool even on the hottest and dustiest of days, and as a rule the few wayfarers one meets scuttle like startled rabbits into the dark recesses on either side, from the depths of which, and through chinks in the wooden doors and windows, they can gape in safety at the unwonted spectacle of European visitors.

Viewed from the outside, say from the ridge of sand which hems in the village on the east side, one sees a vast array of walls, surmounted by screens of dried palm-branches, bound together to form compact hedges affording protection and privacy to those portions of the houses open to the sky. Two minarets rise above the general level, while all around are palm-groves and gardens, with the open desert rising to the western horizon.

Almost the whole of the population is engaged in agriculture, and as in some cases the wells are

situated far from the village, many of the peasants daily ride considerable distances to and fro on their sturdy but diminutive donkeys. There are two or three small shops in the village, but nothing in the nature of bazaars, the chief business transacted being the retailing of Nile Valley goods, such as drapery and groceries. The native women are adepts at basket- and mat-making, and mention must not be omitted of the very attractive spherical baskets made of palm-leaves and fibre, ornamented with coloured wools, and manufactured in every conceivable size and design. Pretty circular trays are made from the same substances; in fact, the number of uses to which the waste materials from the date- and doum-palms can be put is little short of marvellous.

Everything connected with the village is of the most primitive description, and until a very short time ago few of the inhabitants had been beyond the limits of their own fields. The advent of the railway caused no little commotion and stir in the oasis, and awakened trading instincts which had lain dormant since Roman times. Many of the villagers now travel to and fro between Kharga and the Nile Valley, and the Omda took an early opportunity of obtaining leave of absence from his onerous duties, and proceeded to Alexandria for a course of sea-baths!

Outside the village, with the exception of the antiquities, to which we shall call attention in a separate chapter, there is little of general interest

beyond the wells and gardens, among which there are many picturesque spots. At Bir Ain el Gôs, a few kilometres to the north, a primitive form of corn-mill may be seen working, the grinding-stones being driven by the water of the well by means of an undershot wheel.

It may be mentioned here that with very few, if any, exceptions the different streams which collectively make up the water-supply of the oasis find their way to the surface through artificially constructed passages. The great majority of these are bores of ancient construction, though a few have been sunk with modern plant during the last fifty years. The ancient wells are known as Aiyûn (sing. Ain), the modern as Abiyâr (sing. Bir); for example, Ain el Ghazâl, Bir Mansûra. In cases where a modern bore has been specially sunk to replace an ancient well, the two words are used in conjunction; for instance, Bir Ain el Gôs. The position of each well is nearly always conspicuously marked by a thick clump of acacias, from which (more especially in the isolated settlements in the northern part of the depression) the main irrigating channel generally runs in a southerly direction, the cultivated lands being of triangular form, with the apex at or near the source of the water, and raised little, if at all, above the general level of the surrounding plain. By this disposition the fields present the least possible front to the north, from which side comes the bulk of the sand which is such a curse to these outlying settlements.

Kharga village, being snugly situated among palm-groves, and directly to the south of Jebel Têr, is well protected from the fierce, sand-laden winds which so frequently scour the depression from north to south. The poor little hamlet of Meheriq, on the other hand, set on the open plain some 20 kilometres to the north, is exposed to every wind that blows, with the result that the sand has accumulated to such an extent that most of the palms have been buried, and many of the houses have been overwhelmed. The advancing dunes are, in fact, steadily pushing the hamlet southwards. At frequent intervals the occupants of the most northerly houses move their goods and chattels, and betake themselves to new quarters erected at the southern extremity. This periodical migration has, indeed, become so ingrained a habit that it is now regarded as of little moment; it is only when their wells and trees are threatened and destroyed that the wretched people call on Allah to stay His hand, and protect them from destruction.

Still farther to the north lie a number of isolated wells with small areas of cultivation, and at some of these there are settlements consisting of one or two families. Ain el Tawîl, 8 kilometres south-east of Kharga, is another little hamlet, rendered more conspicuous than most of these outlying settlements by the presence of a Sheikh's tomb surmounted by a rather pointed dome. A third important dependency of Kharga is known as Um el Dabâdib, and is situated a day's journey to the

north. This place is of exceptional interest, in that its water-supply is not derived from wells, but from extensive tunnels driven into the hills. Some most interesting ruins exist in the neighbourhood, but a description of these and of the subterranean aqueducts must be postponed to a later chapter.

Twelve kilometres to the south of Kharga lies the village of Gennâh. The intermediate country is largely covered by sand, which in the neighbourhood of the village has accumulated into large dunes, threatening it and its magnificent wells, Ain Estakherab and Ain Magarin, with ultimate destruction. Ain Estakherab is undoubtedly the finest well in the Libyan Desert, and has been running for hundreds, if not for thousands, of years ; but unless special measures are taken to cope with the advance of the dunes immediately to the north and north-west, this splendid flow of water is doomed to destruction within the next ten or twenty years. Owing to the encroachment of the sand there is very little land available for cultivation near the village, the bulk of the water from the two wells being conducted in an open channel to the low-lying plain south-east of the hill-range known as the Gorn el Gennâh. This channel traverses 7 or 8 kilometres of porous desert before it reaches the first of the cultivated fields in the neighbourhood of the Gorn, and there is in consequence very great loss of water through seepage and evaporation.

The famous wells of Gennâh differ from most of

those in the northern part of the oasis in that their mouths are large and deep pools of limpid water, from the depths of which great bubbles of gas constantly ascend to the surface. Little or nothing is known as to the age and depth of either of these wells; they have never been cleaned out in modern times, and are closed in at a depth of a few metres from the surface in such a way as to prevent soundings being made. With the object of determining if the large discharges are due to the wells being situated on exceptionally low ground, I recently had a line of levels run from headquarters to Gennâh. Contrary to expectation, it was found that Ain Estakherab and Ain Magarin discharged at levels considerably above the average elevation of the wells of the Kharga district; possibly, therefore, the exceptional flows in this district are due to its comparative isolation, and to the immunity thus obtained from the interference of other wells.

Between the villages of Kharga and Gennâh, along a north and south belt lying somewhat to the east and on the downthrow side of the fault, are a number of wells whose waters are almost invariably more or less charged with ochre and alkaline salts. In some cases the proportion of dissolved salts is sufficiently great to render the water unfit for either drinking or irrigation, and even where it can be used for the latter purpose, ochre is deposited to such an extent as to bind the soil into a hard cake. The occurrence appears to be due to the geological position of the wells in this tract, where, owing to

the beds being let down by the fault, the purple shales form the floor of the depression; it is perhaps from these beds that the waters derive their abnormally high contents of ferric oxide and other salts.

The wells near Qasr el Ghuâta are of similar nature, and thick banks of ochre have been deposited along their channels. I recollect on one occasion using the water of Ain el Ghuâta for making tea, and being considerably surprised at the inky blackness of the resulting liquid, although, in spite of the colour and a markedly ferruginous taste, the brew was not undrinkable.

Near the ruins of Qasr Zaiyan, and southward as far as the village of Bulaq, the country takes on quite a different aspect, owing to the numerous scrub-covered areas, dotted everywhere with semi-wild doum-palms. Doums thrive in very poor soil, and appear to be self-sown; they are to my mind far more graceful and picturesque than the ordinary date-palms, from which they differ in many important respects. The trunk of a well-grown doum-palm is forked, not once, but many times, the different stems preserving a considerable amount of symmetry; the branches, which are covered with the most atrocious hooks, terminate in sharp-pointed, serrated fan-shaped leaves. The fruit consists of bunches of hard nuts, and can be eaten either in its raw condition or after being ground into meal and cooked; most persons, however, except perhaps confirmed nut-eating vegetarians, would decline it

in either state. Although the country throughout which the doum-palms abound appears to be more or less deserted, every tree has its owner among the inhabitants of the nearest village.

Bulaq, distant 25 kilometres from Kharga, has a population of 1,016, and is the centre of the mat and 'zambile' trade. The zambile is an open wide-mouthed basket which is used in every part of Egypt, and practically replaces the wheelbarrow of western lands. Formerly only small quantities were made for export, but the natives have not been slow to take advantage of the railway, and truck-loads of these baskets may now be frequently seen on the trains. The Bulaq varieties of mats and baskets are mostly made from the leaf of the doum-palm.

The village, bounded on three sides by sand and open desert, with the palm-groves and cultivated lands to the east, cannot be said to be particularly attractive. A few kilometres to the south is the tomb of Sheikh Khalid Ibn el Walîd, a large, square, whitewashed building surmounted by a dome.

CHAPTER VI

THE SOUTHERN VILLAGES

Ain Girm Meshîm—Agûl el Douma—The Southern Villages—Jaja and Dakhakhin—Intermittent Flow and Geyser-like Action of Wells—Ain Dakhakhin—Fruit Gardens—Raised Cultivated Terraces formed of Wind-blown Materials—Gradual Elevation of Wells—Ancient Village of Dakhakhin—Ain Bergis—Beris Village—Ain el Hushi—Block-Houses and Dervishes—Maks Bahari—Method Employed in Cleaning out Wells—Ain Bella—Encroachment of Dunes—Dush—The most Southern Wells of the Oasis—Nakhail.

After leaving the wells belonging to Bulaq the traveller has to cross a stretch of desert about 40 kilometres in width before reaching the first well and cultivated land of the southern group of villages. On this expanse water is only found in one locality—at Ain Girm Meshîm, a pool with a very small flow. There is little doubt that this was at one time a very good well, as traces of irrigating channels extend outwards to a considerable distance; moreover, a large salt-pan is still visible to the west, and this could only have been formed at a time when there was far more water running to waste than at present. The immediate neighbourhood is picturesquely dotted with doum-

palms, some of those near the well being magnificent trees.

Agûl el Douma, lying 17 kilometres south-west of Ain Girm Meshîm, on the opposite (west) side of the belt of dunes, is a place which, previous to my inspection, had probably never been visited by Europeans, although known to a few of the Bedawin. Surface-water can be obtained by digging to a depth of a few feet near one of the doums. The place, marked by a small area of scrub and a doum-palm or two, was formerly used to some extent by Arabs carrying contraband from the south, as by watering here they were able to pass through the oasis unobserved.

The most northerly of the southern villages are Jaja and Dakhakhin, but 6 kilometres to the north lies an isolated group of doum-palms, known as Ain el Douma. At the present time the place is uninhabited, the old well being completely sanded-up, though water may be obtained by digging out the centre. Both north and south of Ain el Douma occur smooth plains of alluvial clay, in the latter direction extending to the villages of Dakhakhin and Jaja.

Jaja is visible from a distance of many kilometres on account of a thick clump of dark green acacias, growing on the summit of an eminence. Dakhakhin, on the other hand, is hidden, being on the south side of a sandy hill covered with short scrub only. A low-lying portion of the alluvial-covered plain separates the two villages, which are situated close together on an east and west line.

At Jaja there are scattered doums and a number of acacias, as well as a small dense grove of date-palms, altogether a goodly number of trees. The well is a broad and deep pool surrounded by vertical walls of brown clay, representing the material from time to time thrown out during the process of cleaning. Large bubbles of gas are generally to be seen rising intermittently to the surface, while at times the pool becomes perfectly still, except for the occasional small bubbles which continue to rise at different points. Then follows a strong flow from the actual bore (situated near the south side of the pool), the water boiling up and breaking the surface with considerable force and noise, which may continue for several minutes before everything becomes quiet again. In all probability the markedly intermittent flow is due to the temporary blocking of the bore-hole by the sediment forming the bottom of the pool, the mud being from time to time forced back by the accumulating pressure of the water and gas below. The temperature of the water was found to be 86° F., and the yield was stated to amount to $1\frac{1}{2}$ qirats, or about 35 to 40 gallons a minute.

Dakhakhin is charmingly situated on the southern slope of an eminence, alongside a dingle, prettily wooded with tamarisk and doum-palms. The well is on the north side, and higher up than the village. One of the irrigating channels, cut out near the bottom of the western slope, follows the winding of the dingle to a thick clump of date-palms near

the mouth. Higher up, alongside the village, the water in another channel races down the hill in a series of little runs and falls, the stream threading its way through fruit-gardens containing date-palms and vines, fig, mulberry, and apricot trees, as well as pomegranates and bananas.

Ain Dakhakhin is a huge pool when full, though at times, when the retaining bank on the south side is cut, a large part of its sandy bed is exposed. The flow, taxed, I believe, as $3\frac{1}{2}$ qirats (110 to 120 gallons per minute), varies at different times of the year, and depends to a considerable extent on the amount of sediment in the pool. Cleaning is periodically undertaken, in order to remove the sand which drifts in from the north side in large quantities.

Neither in Ain Jaja nor Ain Dakhakhin is there any trace of wooden casing similar to that with which the ancient wells of Northern Kharga are so commonly lined. This bears out the conclusion to which I was led on other grounds—that the original outlets were many metres lower than at present, on the level of the surrounding plain, in fact. The eminences of Jaja and Dakhakhin appear to have been formed almost entirely by the gradual accumulation of blown sand and clay-dust, compacted and held together by vegetation. The material is swept by the prevalent winds from the clay plains and sandy deserts lying to the north, and deposited on the cultivated lands, owing to the presence thereon of water and vegetation. Its deposition is encouraged by the peasants, as the

admixture of sand and clay forms a loam of suitable texture for agricultural purposes, and is regarded as having considerable fertilizing value.

There is little doubt that originally nearly all the wells in Southern Kharga had their outlets on the same level as the plain. Owing to the periodical deposition of wind-borne materials, the cultivated lands have gradually risen, until at the present day they form, in the majority of cases, terraces standing well above the general level. This continual raising of the land has necessitated a corresponding elevation of the wells, with the result that the wooden linings originally put into the bores have been completely lost sight of. Instead of issuing from a clean, unobstructed hole, the water has now to force its way upwards through a great mass of sandy mud, and before it can be utilized it has to rise to a much higher level than formerly. Little wonder, then, that the flows of the majority of these wells have very much decreased, with the consequence that the cultivated tracts are much smaller than of old. In more than one case the outlet of a well had, in modern times, risen to such a height that the discharge had become reduced to a mere trickle. Twenty or twenty-five years ago, for instance, Ain Dakhakhin was on the summit of an eminence which, by the slow accumulation of sand and clay, had reached a height of 30 metres above the surrounding plain. Remedial measures were then taken by the inhabitants, and its level reduced by between 8 and 9 metres, the present

level of the well and highest fields being 23 metres above the plain.

The height of a cultivated terrace above the general level of the plain on which the well was originally sunk affords some measure of its antiquity. It is difficult, however, in the absence of observations extending over a number of years, to estimate what the general rate of accumulation may have been. It would, moreover, vary greatly with local conditions, but if an average rate of a centimetre a year be assumed, the age of Ain Dakhakhin is indicated as being something over 3,000 years.

The ancient Dakhakhin lies a kilometre to the S.S.E., and, when inhabited, must have been as ugly as the modern village is pleasing. When the diminution of the flow of Ain Dakhakhin became serious, the people migrated to their present location, so as to be near the well and under the shelter of the hill. The ruins are only slightly above the level of the plain, but cover an area many times greater than that occupied by the modern village. This circumstance alone shows how insignificant is the present flow compared with what it must once have been.

The most northerly of the group of wells in the neighbourhood of Beris is Ain Bergis, situated on the south side of a broad platform of sandy lacustrine beds. In this case there is a containing bank across the valley below the well, but at the time of my visit it was cut, so that the bottom of the pool was

exposed. The latter consisted of a circular basin of soft sediment, through which muddy water was oozing and bursting in small shoots, suggesting an action in many respects analogous to that of geysers and mud-volcanoes. The natives informed me that the basin takes two days and nights to fill after the bank has been closed.

Between Ain Bergis and Dakhakhin stretches a continuous plain of alluvial clay, amounting to several thousands of acres. In its present state this heavy clay land is not regarded as of much value for cultivation, but in the event of new wells being sunk it could be lightened and improved by allowing and encouraging the deposition of blown sand and dust—by following, in fact, the practice which from time immemorial has been in vogue in this district.

The best wells in the neighbourhood of Beris are Johar, Foq el Doum, and El Hushi, the last named yielding 6 qirats, the others 9 each. The remaining wells in the district give from 2 to 4 qirats. In situation and appearance the Beris wells do not differ essentially from those already described, so that we may pass on to a brief notice of the village.

Nothing of particular interest is to be met with in Beris, the chief village of the southern part of the oasis. It is rather exposed, and many of the streets are consequently dusty; in fact some of those on the north side are deep in blown sand. Thick groves of date-palms enclose the village on the east and south sides, but not on the north. The cultivated

lands lie partly to the north and partly to the south-east, but are ineffectual in protecting the village from the dust-laden northerly winds, except to a small extent when the fields are under full crops. The village well is Ain el Hushi, a large bubbling pool some 15 metres in diameter, situated in the palm-groves immediately south of the village.

Solidly-built rectangular mud-brick buildings are found alongside most of the larger wells in the Beris district, and a modern visitor would have some difficulty in guessing to what use they could ever have been put. They were, as a matter of fact, erected by the Egyptian Government during the time of the Dervish raids, to serve as block-houses for the garrisons maintained in the oasis for the purpose of protecting the wells and villages. During this period several notables and petty officials in this and the oasis of Dakhla were carried off by the Dervishes into captivity in the Sudan.

Maks Bahari, the next place to the south, is a tiny little hamlet on the southern slope of a sandy eminence, with extensive clay lands studded with numerous doum-palms, but without water to irrigate more than a small portion of these. The village well is on the south side, and yields about 80 gallons per minute. As usual, it forms a pool contained by a bank, the latter being cut periodically to allow of the well being cleared of sediment.

After the winter crops are harvested in the spring, it appears to be the general practice for the cultivators to pay special attention to their water-supply.

The retaining banks are cut and the water allowed to drain off at the lowest level possible, the wells being sometimes left in this condition for several months, so that they gradually clean themselves with a minimum of trouble to their owners. The mud, exposed on the sides of the basin, continually slides downwards into the central pool, and is carried away in suspension by the outflowing water.

Drift sand has been very destructive in the neighbourhood of Maks Bahari. At Ain Bella, $2\frac{1}{2}$ kilometres to the N.N.W., there are at present only a few acres under cultivation, but the tract anciently tilled is seen in the eroded remnants of an alluvial platform to the north and north-east; this is now a deeply-grooved and ridged hummocky area of loam, full of dead palm-stubs, with rootlets ramifying in every direction. The original terrace appears to have extended far to the north, the portion now remaining being composed of alternating layers of sand and clay, dipping steeply to the south. At the present day many of the cultivated terraces are not only being gradually raised by the continual deposition of wind-borne materials, but are being extended horizontally, owing to the constant additions of layers of sand and clay-dust to the steeply-inclined southern or lee faces. In many respects the growth of these terraces is analogous to that of sand-dunes, though, unlike the latter, the northern portions of the terraces are practically stationary.

At one time or another many wells existed to

the west, but are now buried in the dunes, their former presence being testified by isolated exposures of arable land and by occasional trees and bushes. The dunes, following their natural S.S.E. course in the direction of the prevailing winds, seem to be still encroaching on the belt of country occupied by the existing wells and cultivated lands, and it is probably only a matter of time, perhaps a few hundred years, before they blot out the whole of the south part of the oasis. The sand speedily envelops any settlements which are abandoned, as nothing encourages the formation of dunes to such an extent as vegetation, and this nearly always abounds in the neighbourhood of the wells.

There is little to commend itself to notice at Maks Qibli, the southern of the two hamlets of the same name; there are scattered doums, several groves of date-palms, and small patches of cultivation irrigated by isolated wells, all on high ground. Here, as elsewhere in this part of the country, much land has gone out of cultivation, though it must be mentioned that the villagers are rather progressive in planting trees and maintaining small vegetable gardens.

Dush lies out of the main line of villages, being 10 kilometres east of Maks Qibli, not far from the eastern wall of the oasis. It is a pretty little place, with small clumps of palms, and two white Sheikhs' tombs on the north side. Ain el Burrda, the big well immediately alongside the village, ceased flowing about three years ago, to the great grief of

the inhabitants, who now have to carry their water from Ain el Karm, itself barely running. Fortunately, the great Ain Johar, situated to the south but irrigating land to the north, continues to discharge with unabated vigour. More conspicuous than the village is the ancient Qasr Dush, occupying the summit of a small hill to the east. This will be noticed later.

The wells attached to the hamlets of Dush and Maks mark the limits of the oasis to the south. The most southerly running well of any importance is Ain el Qasr, though Ain Zaha el Din, still farther to the south, just trickles, and irrigates a tiny area of not more than a few square metres. Ain Mabrûka, a kilometre south of the last-mentioned well, is overgrown with green weed, and surrounded by a patch of tamarisk, short prickly scrub, and two or three wild palms. This is the most southerly point at which exposed water is to be seen, though in the midst of a large area of scrub still farther to the south a sanded-up well of the name of Ain el Terfai is reported to exist.

The scrub-covered area of Ain el Terfai is about 25 kilometres south of Beris. To the south the surface gradually rises, and is absolutely devoid of vegetation, the oasis-depression having given way to the true desert. The next available water is at a place called Nakhail, 60 kilometres to the S.S.E.; the water there is good, but only exists in small quantities, obtainable in one or two spots by digging to a depth of a couple of metres.

CHAPTER VII

THE OASIS UNDER PERSIAN AND ROMAN RULE

Previous Descriptions of Archæological Remains—Mr. Lythgoe's Excavations—Dr. Ball's Report—Article by Professor Sayce —Prehistoric Period—Earliest Historical Records—Persian Domination—The Army of Cambyses—Temple of Hibis—Græco-Roman Period—Qasr el Ghuâta—The Roman Emperors—Proclamations on the Temple of Hibis—Qasr Dush—Nadûra—Ruins at Ain Amûr—Qasr Zaiyan and the Town of Tchonemyris—Roman Fortresses—Dêr el Ghennîma —Qasr Lebekha and Um el Dabâdib—Monasteries—Watch-Tower in Bellaida—Introduction of Christianity—The Christian Necropolis—Representations of Biblical Scenes and Personages—Embalming—Celebrities banished to the Oasis—The Columbaria—Olympiodorus describes the Fertility of the Oases under the Romans.

THE archæological remains of the oases have been referred to, and in some cases described in more or less detail, by most of the travellers who have left any records of their journeys in the Libyan Desert. Among the latter may be mentioned Cailliaud, Hoskins, Schweinfurth, and Brugsch. At the same time, compared with the antiquities of the Nile Valley, those of the oases have received scant attention; indeed, it is only within the last year or two that any systematic excavations have been undertaken. At the present time Mr. Lythgoe, assisted

by Mr. Winlock, is excavating in the neighbourhood of the Christian Necropolis, for Mr. Pierpont Morgan, on behalf of one of the American museums, and the results promise to be of the greatest interest and importance. It is to be hoped, therefore, that, in a few years, we shall be in possession of a detailed and authoritative account of the history of the oasis during the last few thousand years, as it must be admitted that the only information available at the present day is woefully scrappy and in many respects unreliable. Ball, in his report on Kharga published in 1900, gave an excellent summary of all that was at that time known concerning the antiquities, together with a number of useful plans of the chief buildings. Since that date, with the exception of a press article by Professor Sayce, little, if anything, has been published.

Without making any pretensions to special archæological knowledge, I shall attempt to give a brief sketch of the past history of the oasis, at the same time drawing the reader's attention to the distribution and general characters of the more important remains.

Although the oasis of Kharga was doubtless inhabited in prehistoric times, as, indeed, is shown by the existence of flint implements of Palæolithic type on the surrounding plateaux, and also to a lesser extent within the depression, no graves referable to the prehistoric period of Egyptologists —*i.e.*, the period immediately preceding that known as the first dynasty, when Menes united Egypt about

3,300 B.C.*—have as yet been discovered. But while it is known that the Egyptian kings claimed the allegiance of the inhabitants of the oases as far back as the eighteenth dynasty (1545-1350 B.C.), the earliest known monumental records in Kharga date from a much later period—*i.e.*, the twenty-seventh dynasty —when Egypt was under Persian domination.

It was at this time that Cambyses, in an endeavour to subdue the inhabitants of the outlying oases, lost a large portion of his army in the Western Desert, probably somewhere to the west or north-west of Kharga. The Persian monarch had recently defeated the Egyptian king, Psammetikh III., at Pelusium, and made Egypt a Persian province. On his arrival at Thebes some 50,000 men were detached from the main army proceeding to Ethiopia, and ordered to march against the Ammonians and burn the oracular temple of Jupiter Ammon. This abortive expedition into the Libyan Desert is described by Herodotus ('Thalia,' 26) as follows:†

"The men sent to attack the Ammonians started from Thebes, having guides with them, and may be clearly traced as far as the city Oasis, which is inhabited by Samians, said to be of the tribe Æschrionia. The place is distant from Thebes seven days' journey across the sand, and is called in our tongue 'the Island of the Blessed.' Thus far the army is known to have made its way; but

* The dates given in this chapter are those assigned by Professor Steindorff.

† Canon Rawlinson's translation.

thenceforth nothing is to be heard of them, except what the Ammonians, and those who get their knowledge from them, report. It is certain they neither reached the Ammonians, nor ever came back to Egypt. Further than this, the Ammonians relate as follows: that the Persians set forth from the Oasis across the sand, and had reached about half-way between that place and themselves, when, as they were at their midday meal, a wind arose from the south, strong and deadly, bringing with it vast columns of whirling sand, which entirely covered up the troops, and caused them wholly to disappear. Thus, according to the Ammonians, did it fare with this army."

In modern times considerable doubts have arisen as to which oasis was the objective of this army, and certainly the description of Herodotus is such as to admit of various conclusions being drawn. Rohlfs considers that Dakhla, not Siwa, was its goal, and remarks that, however light-headed Cambyses might have been, he could hardly have been so foolish as to have chosen Thebes as the starting-point of an army destined for Siwa. The same writer points out that a temple dedicated to Ammon does exist in Dakhla, and that the distance of the latter oasis from Thebes corresponds with the ten days mentioned by Herodotus. Vivien de St. Martin ("Le Nord de l'Afrique dans l'antiquité," 1863, pp. 40-41) had, some twelve years previously, come to somewhat similar conclusions.

Ascherson, on the other hand, regards it as

highly improbable that Dakhla, which was hardly known and certainly of little importance in the time of Cambyses, could have been the objective of so dangerous and difficult an undertaking, and points out, moreover, that the temple of Ammon in that oasis dates from much later (*i.e.*, Roman) times. He further remarks that Parthey ('Das Orakel und die Oase des Ammon,' Abhandl. der Akademie der Wissenschaften in Berlin, 1862, S. 131-194), in a contemporaneous work, had already met the objections raised by Vivien de St. Martin. According to the ancient maps the distance from Memphis to Siwa was much the same as that from Thebes to Siwa. No reliance, moreover, can be placed on the distances given by Herodotus. Judged with reference to Thebes, the country of the Ammonians certainly agrees more or less with the position of the oasis of Dakhla; but considered in relation to Augila (a place which has retained its name unchanged up to modern times), it corresponds with the modern Siwa, where the well-known oracular temple of Jupiter Ammon actually existed.

It seems to me quite reasonable to suppose that Cambyses only decided on the despatch of this expedition after reaching Thebes, and from there the route, via Kharga, Dakhla, and Farafra, would be fairly direct, and have the advantage of passing through oases, well provided with water and food-supplies, separated by marches not exceeding four days. Possibly, moreover, the 'oasis' through

which the army is recorded to have safely marched may not have been Kharga at all, but Baharia, or even Farafra, either of which would have been reached by striking into the desert along one of the roads leaving the Nile Valley in the neighbourhood of Assiut or Mellawi; this would have been quite a likely route for an army starting for Siwa from Thebes, as over a third of the distance would have been along the fertile plains bordering the Nile.

The evidence, however, seems to favour the view that the army proceeded westwards from Thebes, and passed safely through Kharga, possibly also through Dakhla; in those days the latter may have been coupled with Kharga, as it was later, when the two together were called the Great Oasis. As it is impossible to imagine a body comprising 50,000 men being destroyed by a sandstorm, I am inclined to agree with Hoskins that the army was purposely misled and sacrificed by the guides, with the object of preventing the capture of Siwa and the destruction of the far-famed temple of Jupiter Ammon. In the deserts to the north and west of Dakhla immense accumulations of sand cover, without a break, thousands of square miles of country; only one or two possible tracks cross this lonesome wilderness, and these, following narrow troughs hemmed in by hills of sand, are invisible even from the distance of a few hundred yards. Only a party thoroughly acquainted with desert travelling could hope to penetrate this region, and nothing would be easier than to encompass the loss

of a large and unwieldy army among these terrible dunes. It seems probable, moreover, that this body of troops was as ill-equipped and badly led as the main army which at the same time was marching southwards to Ethiopia. Led by circuitous routes till they reached a point many marches distant from the nearest well, worn out by the incessant clambering over endless ridges of soft sand, their stores of water and food exhausted, their tracks obliterated by the ever-moving sand, the fate of the unfortunate soldiers, deserted at the last by the treacherous guides, could not long have remained in doubt.

The Persians left a magnificent record of their rule in the temple of Hibis, situated 4 kilometres north of Kharga village. Founded (or possibly only rebuilt) by Darius I. between 521 and 486 B.C., in honour of the god Ammon-Ra, it was enlarged by Nektanebos about 150 years later. In the hieroglyphics the King is mentioned as having built the temple of good white stone, and as having covered its portals, made of Libyan acacia-wood, with bronze from Asia. There are long lists and representations of the offerings made to Ammon-Ra the sun-god, commencing with the wine of the oasis. The building is situated in the midst of fields and palm-groves, and the accompanying illustrations give a good idea of its general aspect and architecture. The main portion has its long axis east and west, and measures 44 by 19 metres, the walls being about 6 metres high. To the east of the chief entrance there are three isolated pylons,

one of them being at the present day almost hidden by palms. The entire building is constructed of Nubian Sandstone, believed to have been obtained locally, though the quarry has never been located. Hibis means 'the town of the plough,' and is referred to in the Ptolemaic inscriptions at Edfu as the capital of Kenem (Kharga). It is not certain whether the town, which probably existed into the Middle Ages, was in the immediate vicinity of the temple, or, as suggested by Rohlfs, near Nadûra, a smaller edifice on a marked eminence a little to the south-east.

Apart from the temple of Hibis most of the antiquities in the oasis belong to the Græco-Roman period, and probably the most interesting and important of these is the temple now known as Qasr el Ghuâta, situate 6 kilometres south-east of Gennâh, on a conspicuous eminence composed of sandstones and shales. Qasr el Ghuâta dates from the time of the Ptolemies, and, as the cartouche of Ptolemy III. (Euergetes I.) appears on the entrance walls, it may be presumed that it was erected during his reign, between 247 and 222 B.C. The actual temple is of sandstone, and measures approximately 10 by 20 metres, the main entrance being richly inscribed and having ornamental columns with beautifully designed capitals. The interior consists of three courts or rooms, the first plain, the second with four ornamental columns and walls decorated with exceptionally well-cut hieroglyphics, while the third is much smaller, and contains enclosed passages and

cells. The building is hemmed in by numerous crude enclosures, with partitions of sun-dried brick, the whole of which, forming a large rectangular block, was originally surrounded by a high brick wall of considerable thickness. According to Schweinfurth, the outer crude erections formed the quarters of a garrison at a later date.

It was during the sway of the Roman Emperors that the Egyptian oases attained their maximum importance. During this period, from 30 B.C. to about the beginning of the seventh century, extensive towns existed in Kharga, and the oasis was strongly garrisoned and protected by forts. Temples and other edifices were erected, while a great development of the water-supply took place. During the same period the oases were used as places of banishment, just as they were in earlier days under the Pharaohs, and have been, in a way, in quite modern times. Juvenal, the Latin satirist, was banished to Syene at the beginning of the second century, as a punishment for his attacks on the Court, and he appears also to have been for a time confined in Kharga; Athanasius, Nestorius, and other celebrities likewise made unwilling acquaintance with this portion of the Empire.

Sayce remarks that the oases under the Romans were thoroughly cultivated, a brisk trade in wine being carried on, and mentions that on one of the temple walls there are several inscriptions which lead one to infer that Kharga yielded a considerable revenue. One of the best known,

dated in the first year of the reign of the Emperor Galba (A.D. 68), is a long Greek inscription on one of the pylons of the temple of Hibis; this has been carefully copied by more than one traveller, and translations have been published by Young, Letronne, and Hoskins. In it the Prefect of the oasis, Julius Demetrius, communicated the answer of the Governor of the province, Tiberius Julius Alexander, to various complaints made by the inhabitants, not only of the oasis, but of other districts under the same jurisdiction. The proclamation admits the justice of the complaints, and lays down at great length the steps to be taken in regard to the appointment of tax-gatherers, the payment of debts, and imprisonment for various offences; it deals with deeds of sale, the marriage portions of women, rents, military service, legal appeals, the punishment of libellous informers, etc.; forbids extortion and exorbitant taxes; orders the restitution of illegally exacted moneys; and ordains that taxes are to be based on the extent of the Nile inundation.

A still earlier inscription, on the southern portion of the same pylon, refers especially to the inhabitants of the oasis, and is translated by Hoskins as follows:

> "Cnœus Virgilius Capito says: I have both heard long ago some unjust expenses and false charges to be made by certain persons avariciously and shamefully abusing their powers: and I have just now been informed, that in the territory of the Libyans certain things are consumed by those seizing them under pretence, as it

were, because of their necessities, as being set apart for their expenses and entertainments; which charges are neither true nor admissible: and in like manner under the name of the service of couriers. Wherefore I command those travelling through the nomes, soldiers, and horsemen, and serjeants, and centurions, and tribunes, and all others, to take nothing nor to exact the privileges of couriers, except certain have my warrants; and these passing along only indeed to be accommodated with lodging: and that it be laid down, that no man do any thing, beyond what were established by Maximus. But if any individual may give, or consider any thing as given, and exact as for the public service, I will exact ten times the amount of what he has exacted from the nome, and give a four-fold portion to the informer out of the property of the condemned. The royal scribes, and the village clerks, and the clerks of the districts in each nome, shall keep a register of all, that is expended by the nome upon any one: that, if this or any thing else has been irregularly committed, they may be recorded, and may repay sixty-fold. But the inhabitants of the Thebaid may for four months come up to the tribunals of accounts: and let them address themselves to Basilides, the freedman of Cæsar, an officer of the tribunal of accounts, and to the comptrollers; that, if any thing may be adjudged or done contrary to what is just, I may in like manner put this in order."

These are interesting side-lights on life in the oasis in those days, and show that the people were well treated by their highly gifted foreign rulers, who, as is well known, respected the customs and religion of the Egyptians and other nations over whom they ruled.

Although there exists in the neighbouring oasis of Dakhla a temple erected during the reign of Vespasian, the earliest Roman temple in Kharga

is probably Qasr Dush, the ancient Kysis, erected by Trajan in A.D. 117, and dedicated to Isis and Serapis. The temple, standing in the midst of the ruins of a town, occupies the summit of a hill a couple of kilometres north-east of Dush. The main building, constructed of stone, has its long axis north and south, and measures 15 by $7\frac{1}{2}$ metres. It is preceded by a forecourt, in front of which are two pylons, the first bearing a Greek inscription relating the date of its erection. Hoskins gives the following translation of this inscription:

> "For the fortune of the Lord Emperor Cæsar Nero. . . . Trajan Optimus Augustus Germanicus Dacicus, under Marcus Ruffinus Lupus, Governor of Egypt, to Serapis and the supreme gods, those of [Cyrene ?] having written, erected from a principle of piety this building. The nineteenth year of the Emperor Cæsar Nero Adrian Optimus Augustus Germanicus Dacicus."

There appears originally to have been a colonnade between the first and second pylons, but only fragments of the columns exist at the present day. The front of the forecourt is covered with hieroglyphics, while the interior is unsculptured except at the portal leading to the main hall, the latter measuring 6 by $5\frac{1}{2}$ metres, and having four columns. On the west side there is an entrance leading to an inclined passage. The northern part of the building consists of a central semi-divided portion flanked by two elongated chambers, all of which have arched roofs. A parapet is formed by the external walls of the temple, while the roof over the three southern

chambers is at a lower level than that of the main hall.

The temple proper is in the western portion of an immense rectangular enclosure bounded by very thick walls of sun-dried brick; these walls at the present day are in a very bad state of preservation, but appear to have been of the type common in some similar buildings in the north of the oasis—*i.e.*, hollow at the top, so as to enclose a passage by means of which the custodians could make the circuit of the building without descending, and from which, unobserved from the exterior, they had the advantage of a splendid view of the surrounding country. The measurements and details which I have given above are largely taken from Dr. Ball's report, to which the reader is referred for plans and sections of this and other temples.

One of the most conspicuous ruins in the oasis is the little temple of Nadûra, situated on a hill 1 kilometre south-east of the temple of Hibis. The inner building is of sandstone, and roughly measures 8 by 11 metres, while the outer portion, bounded by walls of unburnt brick, is very much larger. According to Sayce, the temple was built by Hadrian between A.D. 117 and A.D. 138. Brugsch, however, refers it to a somewhat later date, considering it to have been erected by Antoninus Pius. Several smaller ruins in the neighbourhood are probably referable to the same period as the temple itself.

The ruins of Qasr Zaiyan, $5\frac{1}{2}$ kilometres north-

east of Bulaq, enclose a small sandstone temple of somewhat doubtful age, though a Greek inscription over the entrance records that the building was restored by Antoninus Pius and dedicated to Amenebis (Ammon of Hibis), god of Tchonemyris, the ruins of which town exist in the vicinity. The inscription is translated by Hoskins as follows:

> "To Amenebis, the supreme god of Tchonemyris, and to the associated gods of the temple, for the eternal preservation of Antoninus Cæsar our Lord, and his whole house. The cell of the temple and the vestibule were repaired and renewed under Avidius Heliodorus, governor of Egypt; Septimius Macro being commander-in-chief, Plinius Capito being general of the forces, in the third year of the Emperor Cæsar Titus Ælius Adrianus Antoninus Augustus, the Pious. Mesore the eighteenth."

The Emperor Antoninus Pius reigned from A.D. 138 to A.D. 161, but antiquities unearthed from the ruins show that the town dates from the time of the Ptolemies and flourished into the Byzantine period.

In addition to the above the dilapidated ruins of what were doubtless once imposing buildings exist at various points within the depression. One worthy of attention will be noted at Ain Amûr by travellers to Dakhla along the upper road. The exact age of the building is uncertain, though Wilkinson discovered thereon a portion of the name of one of the Cæsars. The small stone temple stood, like so many others in the oasis, in a courtyard enclosed by thick walls of unburnt brick, the fragmentary remains of which are visible in the illustration.

The names of the principal deities inscribed on the temple walls are Kneph, Ammon, and Mut. Both Edmonstone and Wilkinson came to the conclusion that the temple is of greater antiquity than the majority of the monuments of the oasis; but I am inclined to believe, with Hoskins and Rohlfs, that its somewhat crude design is explicable on other grounds than that of age.

Perhaps the most remarkable and imposing buildings in the oasis are the great Roman fortresses, among which may be mentioned Um el Dabâdib, Qasr Lebekha, and Dêr el Ghennîma. Possibly some of these were fortified monasteries, though until the ruins, as well as those of the extensive towns and cemeteries which existed in the neighbourhood, have been subjected to critical examination, their exact nature must remain in doubt. The so-called Dêr, near the foot of Jebel Ghennîma, was certainly a fort guarding one of the chief passes up the escarpment of the oasis. It is built of immensely thick walls, strengthened intermediately and at the four corners by enormous buttresses. The walls taper slightly upwards, and at the top are double, concealing a passage which ran round the entire building. In the centre of the court was a deep bore from which the inmates obtained their water, the surplus supply flowing through an underground conduit to the cultivated lands outside.

Qasr Lebekha, situated in a lonely part of the depression under the northern escarpment, 12 kilo-

metres north-west of Meheriq, has many points in common with the fortress just described. It is, however, much smaller, and its interior is completely filled with domed chambers, now falling into shapeless fragments.

The impressive ruin at Um el Dabâdib, 36 kilometres N.N.W. of Kharga, seems to me to have been a fortified monastery, the interior being filled with vaulted cells. Its appearance is quite distinctive, lacking as it does the round buttresses of Qasr Lebekha and Dêr el Ghennîma, though the walls are still of great thickness, and loopholed for defence. Outside are the remains of a town of considerable size, and here doubtless several hundred workmen were quartered when the extensive subterranean waterworks, which exist in the locality, were in course of construction.

A fourth large ruin, of somewhat similar architecture, occupies a conspicuous position on the edge of the escarpment overlooking the Bellaida district, about 2 kilometres north of the temple of Hibis. Ball describes this under the name of Qasr Ain Mustapha Kashef, a name which, of course, merely refers to its position near a well of that name. The interior consists of tiers of arched chambers, and according to Schweinfurth there is little doubt that the building was a monastery.

All the above-mentioned forts and monasteries are built of large sun-dried bricks measuring, as a rule, 35 × 17 × 9 centimetres, and it is noteworthy that the walls, where of exceptional thickness, were

built in sections, perhaps to allow of their drying more readily. Besides those described, a great many other mud-brick buildings are to be found scattered through the oasis, the majority of which possess no very distinctive features. One, however, being sure to attract the attention of visitors may be specially referred to ; this is a high rectangular tower occupying a very conspicuous position on the open plain to the west of Jebel Têr, measuring 5 by 6½ metres at the base, the walls tapering slightly upwards to a height of about 15 metres. It was originally divided into storeys and provided with a staircase, and may very probably have been used as a watch-tower. The remains of a circular brick or pottery kiln are to be seen twenty paces to the south.

The exact age of these numerous brick buildings cannot be stated with certainty, and we can only hope that when the pottery, coins, and other objects which exist in the ruins of the adjoining towns have been systematically collected and examined, it may be possible to date them with more accuracy. At present we can only conjecture that while the greater number were erected during the Roman occupation, between 30 B.C. and A.D. 395, some of them may date from the succeeding Byzantine period. Many of the cemeteries contain mummy-cases on which the likeness of the deceased is carved in wood on the outside, or fashioned in stucco and painted in colours. Three of these from an ancient burial-place in the Bellaida district, between Jebel Têr and Jebel Tarif (one of a number of cemeteries

of Roman age which await the attention of archæologists), are shown in one of our illustrations.

Christianity was introduced into Egypt in the early part of the Roman domination, and spread rapidly through the country, although the national Egyptian or Coptic Church was not established until A.D. 451. Judging by the size and importance of the cemetery at the south end of Jebel Têr, and by the numerous monasteries, Christianity must have had a great following in the oasis of Kharga. During this period many of the temples in Upper Egypt were converted into churches, and it was not until A.D. 640, when the Caliphs conquered the country, that Christianity began to wane.

The Christian Necropolis lies 1 kilometre north of the temple of Hibis, on the southern extremity of the foot-hills of Jebel Têr. The cemetery, known at the present day as 'El Baguat,' consists of a great number of tombs built of unburnt brick, the majority showing a considerable amount of architectural decoration. The buildings cover a large area, and are to a certain extent laid out in streets, which, as Ball remarks, give the place the appearance more of a strange deserted town than of a graveyard. Some are small tombs, noticeable for their simple beauty; others are large mausolea and sanctuaries, richly ornamented with columns, pilasters, and arches. Almost without exception the tombs are surmounted by domes, though, owing to the walls being carried up beyond the base of the dome, the latter is not always conspicuous from

the outside.* The interior walls are invariably plastered and whitewashed, and covered with numerous Greek and Arabic inscriptions, the old Egyptian 'Tau,' the sign of eternal life, being frequently displayed. In addition, the walls and domes are in some cases ornamented with crude coloured designs. The pictures have, unfortunately, been mostly hacked to pieces or covered by Arabic writings, so that there are now only two tombs in which the original paintings are anything like intact. On the dome of one of these, near the south end of the cemetery, a number of familiar Biblical personages are represented in colours, their names being inscribed in Greek characters immediately above. Adam and Eve, Noah, Abraham, Sara and Isaac, Christ, Paul, and others are clearly distinguishable.

The actual grave is below the centre of the floor of each tomb. The bodies, which mostly appear to have been embalmed and wrapped in cloth, have in many cases been plundered of ornaments and thrown out. Even at the time of Hoskins' visit in 1837 the majority of the tombs had been ransacked, and at the present day there are probably few left intact. With regard to the practice of embalming, Hoskins writes: "It is highly satisfactory that we have such indubitable evidence

* That even occasional rains can effect a considerable amount of erosion of soft materials is shown by the present state of these domes, from which a skin of some thickness has been washed away, leaving the surfaces bristling with the sharp fragments of rock which were included in the original mixture of sand and clay from which the bricks were manufactured.

to enable us to establish the fact, that the custom of embalming the dead was continued by the first professors of the Gospel in Eastern Africa. The introduction of Christianity produced great and sudden changes in the minds, habits, and customs of believers; but a length of time was no doubt often necessary to root out many of the prejudices of the people; and it is very possible, that the practice of embalming may have been continued as a necessary mark of respect to the dead, long after the doctrine had been entirely exploded, in accordance with which the custom had been originally established. This practice, however, even in the most ancient times, was not confined to the worshippers of Amun. The physicians of Egypt were forty days in embalming Jacob; and Joseph also was embalmed in Egypt."

We cannot speak with certainty as to the exact period during which this cemetery was in use. In the course of the reign of Constantius (337-361), Athanasius, the champion of the doctrine of the Trinity, was several times expelled from Alexandria and compelled to take refuge in the Libyan Desert, where there were numerous monasteries, which afforded safe asylums from the followers of Arianism and Paganism. Hoskins states that the name of Athanasius occurs in one of the Theban sepulchres, and he believes that "the ruined monasteries in the Oasis Magna were, probably, the abode of the great champion of the Christian religion."

During the reign of the Emperors Arcadius and

Honorius numerous personages, including the general Timasius, were exiled to the Great Oasis, described by a writer (Zosimus) as "a barren place whence no one could escape when once carried thither; for the way being sandy, desert, and uninhabited, no one can find it, the wind covering the traces of people's feet, nor is there any tree or house to guide them."

Nestorius, Bishop of Constantinople, was excommunicated and banished to the oasis in A.D. 434 by the Patriarch Cyril of Alexandria, and probably the necropolis contains the tombs of a large number of his followers. The Bishop, however, did not die in Kharga, as he was carried thence into captivity by the Blemmyes, the ancestors of the Bisharin and Ababdeh Arabs, and died, after suffering great persecutions, at Panopolis (Akhmîm) about the year 440. It is interesting to note that certain Christian customs and festival days are still observed in the oasis at the present time.

Ruins of columbaria are of frequent occurrence in many parts of Kharga, and judging from the size and shape of the bricks used, belong to the same period as the forts and monasteries. They are generally of considerable size, the inner walls being built so as to provide tiers of cubical niches to serve as nesting-places for the pigeons. Examples may be seen at Ain el Burg and Ain Tabashîr in the Meheriq district; in the Bellaida country, and near Ain Khenâfish; on the slopes of the Gorn el Gennâh; and near the village of Dush at the south end of

the oasis. These ancient pigeon-houses are called 'Burg' by the natives, the Arabic name for dove-cot being 'Burg Hamâm.'

That the oases were very flourishing under the Roman Empire is shown by Olympiodorus, who lived in the reign of Theodosius II. (A.D. 408-450), and was born in Upper Egypt. Writing of the Great Oasis, he calls attention to its salubriousness, to the abundance of sand everywhere, and to the numerous wells, which, sunk to a depth of 200, 300, or even 500 cubits,* pour forth streams of fresh water at the surface, which is used in rotation by the owners for the irrigation of their fields. Barley, he avers, is sometimes sown twice a year, and millet almost always three times. Writing of the irrigation, Olympiodorus remarks that in this region the sky is always cloudless, and that the great fertility of the land is attributable to the fact that the peasants water their little enclosures every third day in summer, and every sixth in winter. The same writer states that dials were made in the oasis.

The presence of marine shells in the rocks of the surrounding deserts led Olympiodorus to conjecture that the oasis was formerly an island, separated by the sea from the rest of Egypt, and he recalls the fact that the place was called by Herodotus 'the Island of the Blessed.'

* The royal cubit was the chief unit of length, and measured 20·6 inches; 300 and 500 cubits would therefore be equivalent to 515 and 858 feet respectively.

Strabo writes of the Libyan Desert thus: "This continent resembles a panther's skin, as being spotted with inhabited districts, insulated in the midst of a sandy soil and arid deserts; the Egyptians call these cantons 'Auasis.'" He refers to the Great Oasis as follows: "In a parallel line with Abydus, and distant about three days' journey across the desert, we find the first of the three Oases of Lybia; it is a spot well inhabited, well supplied with water, and producing wines and other commodities in sufficient abundance."

With the withdrawal of the Roman garrisons and the Mohammedan conquest decay set in, and, as Sayce remarks, the aqueducts became choked, the fields were neglected, and malarial fever invaded a district which had at one time been regarded as a health resort.

Of the history of the oases during the succeeding seven or eight centuries no records are available, but, judging from the writings of Arabian geographers, between the eleventh and the fifteenth centuries, it is evident that they gradually became depopulated, and were regarded as of little importance. El Sherîf el Edrissi, writing about the middle of the sixth century of the Hegîra, refers to the oases (Al Vahat) as places formerly containing streams of water, with lands on which trees were still found growing, and with ruined, uninhabited towns. He adds that the goats and sheep had become quite wild, and were trapped by hunters like other wild animals. It is not improbable,

however, that this author was referring to some of the smaller oases-depressions, such as Kurkur, or perhaps to some of the more outlying parts of Kharga or Dakhla. It seems extremely unlikely, as Hoskins remarks, that the Great Oasis as a whole had become entirely uninhabited.

Still later the emir and historian Ismail Abulfida, about the beginning of the fourteenth century, speaks of the oases as abounding with palms and running water, and describes them as situated like islands, in the middle of the desert, three days' journey from the Said (Upper Egypt). Jacutus describes the positions of three oases, and refers to the first of them as being well cultivated, containing streams and hot springs, palms and cultivated lands. The inhabitants, he adds, are in a wretched state. Several other writers allude to the Egyptian oases, but their information is seldom, if ever, first hand, and the descriptions are in general so vague that we are left in doubt as to which particular oasis their remarks refer.

The more modern records, commencing with those of Poncet at the end of the seventeenth century, have already been referred to in a previous chapter.

CHAPTER VIII

THE EXTINCT LAKES OF THE OASIS

Character and Extension of Lacustrine Deposits—Modern Erosion by Wind-borne Sand—The Lakes geologically of Recent Age—Discovery of Pottery and Bones of Domesticated Animals—Area occupied by the Lakes—Maximum Level of their Waters—Lacustrine Strata at Gorn el Gennâh—Relation to the Ancient Monuments—Altitudes of Archæological Sites—Age of the Lakes and their Persistence into Historic Times—Flint Implements—Origin of the Lakes—Their possible connection with the Artesian Waters—Lacustrine Deposits form the Cultivated Lands of Modern Times.

WHEN in 1906 I commenced to make a special study of the geology of the oasis, with a view to elucidating certain questions which had arisen in connection with the water-supply, it came to me as a very great surprise to find indubitable evidence that the greater part of the floor of the depression had at one time or another been the site of an immense lake. No mention had been made by previous observers of the extensive accumulations of lacustrine sediments which cover so large a proportion of the floor, and are found from near Ain el Ghazâl in the north to beyond Beris in the south.

These deposits consist of horizontal finely-bedded alternations of sand and clay, or more frequently of an intimate mixture of the two; local false-bedding is not uncommon, and included fragments of limestone or sandstone are occasionally met with. The beds have a prevailing brown tint, and frequently exhibit well-marked hexagonally disposed shrinkage cracks. Although originally they must have formed an immense compact and continuous sheet, the deposits have since been subjected to considerable denudation, so that at the present day they exist as large isolated patches. Perhaps the most striking of these is that occupying the centre of the depression between Kharga village and Jebel el Ghennîma, covering an area of between 40 and 50 square kilometres, and over the greater part cut by the sand-blast into thousands of isolated hummocks, disposed with their longer axes parallel and in the direction of the prevailing north winds. Individual hummocks have perhaps an average height of 4 or 5 metres, though many exceed this considerably; in length they may measure anything up to 40 or 50 metres. The northern end of a hummock is in nearly all cases the larger, the gradual tapering towards the south being a most distinctive feature. Their present shape and appearance are, of course, entirely due to the eroding and sculpturing action of sand-laden wind.

The finding of these extensive lacustrine deposits naturally opened up a number of questions of the greatest interest and importance. To what level

had the waters of the lake attained; what were its limits horizontally; and, most important of all, at what period had it existed, and what were its relations to the ancient monuments of the oasis? With the object of solving these problems it has been my endeavour to collect all possible information concerning the deposits, and, although it is perhaps too soon to draw inferences with any great certainty, I propose to put on record such data as I have been able to obtain, and to indicate the conclusions to which they appear to lead.

It is, of course, obvious that the lake was, geologically speaking, of comparatively recent date; the lacustrine deposits have nothing in common with those of the Cretaceous and Eocene formations which build up the plateau-massif out of which the oasis-depression is hewn. The sands and clays are much softer and less consolidated beds, laid down superficially and unconformably on the uneven surfaces of the older formations; the depression had, in fact, almost attained to its modern dimensions before the beds in question were formed. My first impression was that the lake dated from prehistoric, if not prehuman, times; that it existed before the prevailing desert conditions set in, when the Nile Valley was the site of extensive lakes and the country was partially wooded. The existence of thick deposits of calcareous tufa on the upper portions of the cliffs of the depression suggested a considerable outpouring of water from springs, and it seemed not improbable that the surplus

water collected on the floor of the depression below.

For some time I was unable to discover any clue to the age of the deposits, in the shape of organic remains or human relics. Then, in a pit sunk for surface-water in the neighbourhood of Headquarters,* some fragments of pottery were found at the base of the deposit. This discovery was followed by the finding of other pieces of pottery firmly embedded in some of the clay hummocks to the south-west of Headquarters. These were without question *in situ*, and proved that the lake was contemporaneous with man.

Further search, in which I was greatly assisted by my friend H. H. Baker, M.B., led to the discovery of human settlements, apparently on the margins of the lake. In these localities large quantities of broken pottery were found associated with the bones of domesticated animals, while the fresh-water gastropod shell, *Melania tuberculata*, was found to be abundant in some of the beds. Careful exploitation of one or two of these sites, about 6 kilometres south-west of Headquarters, enabled us to procure a number of complete earthenware vessels, the chief types of which are shown in one of our illustrations. A comparison of these with pottery of known age must be left until we have referred to the horizontal and vertical extension of the lake.

* The Headquarters of the Corporation of Western Egypt, Limited (see map).

Judging from the still existing deposits, and utilizing (in the northern part of the oasis) a considerable number of levels, I believe the limits of the lake to have been as shown on the accompanying plan. From its most northerly point in lat. 25° 45′ N., in the neighbourhood of the modern Ain el Ghazâl, its western boundary trended S.S.W., passing about 1½ kilometres west of Meheriq village to the south-west end of Jebel Têr; thence its shore-line lay at the foot of Jebel Tarwan, rounding which it projected somewhat into the Bellaida district between Jebel Têr and Jebel Tarif. South of this it bore slightly west of south, passing about 2½ and 3 kilometres west of Kharga and Gennâh villages respectively. From the latter point the shore-line proceeded almost due south to lat. 25° 2′ N., in the vicinity of Ain Girm Meshîm.

Its eastern limit appears to have been about a kilometre east of Ain el Qasr, and some three times that distance east of Meheriq, so that on this latitude the lake had a breadth of 4½ kilometres. In the neighbourhood of Headquarters its margin lay 2 kilometres to the east, whence it ran almost due south for about 12 kilometres. Here, just to the south-west of Ain Harrân, the lake attained its greatest width—*i.e.*, 15 or 16 kilometres, gradually diminishing southwards to Ain Girm Meshîm. The total length of this portion of the lake was just over 80 kilometres.

Both at Ain Girm Meshîm and Ain el Doum the

lacustrine deposits are well seen; over the intermediate country they were not observed, and as this area lies at a somewhat high elevation, it seems probable that there was a break in the continuity of the lake of about 15 kilometres in extent.

The southern portion appears to have measured approximately 45 by 15 kilometres, its long axis lying along a line passing through Ain el Doum, Beris, and Maks Qibli. To the south-east the lake had a local extension in the neighbourhood of Dush. It is thus seen to have extended, with a possible break of a few kilometres in the district near Ain Girm Meshîm, almost throughout the length of the depression, over a distance of 136 kilometres, or 85 miles.

It proved a matter of some difficulty to determine the maximum height to which the lake had reached, as in most localities the deposits have suffered considerable denudation, and their margins are usually obscured by blown sand and superficial detrital material. The pottery to the south-west of Headquarters was ascertained to occur at 47 metres above sea-level, the uppermost limit of the deposits in that area being 62 metres. At Headquarters the lake clays occur up to between 65 and 66 metres; at Ain Terfai and Ain Mahmud, north of Meheriq, to 65 and 67 metres respectively. Still farther north I found there were stretches of similar clays at 76 metres near Ain el Qasr, and at 84 to 85 metres in the neighbourhood of Ain el Ghazâl.

On the west side a very well-defined plain formed of the lake beds occurs immediately to the east of the Necropolis, and was found to lie at 70 metres above sea-level. But the most valuable data of all were those obtained at the Gorn el Gennâh. There, as anticipated, the lacustrine deposits, containing *Melania* and *Limnæa* in abundance, were found to be well developed and exposed, being piled up on the flanks of the hill on its north, east, and south sides, the exact limits of the beds being best seen on the south-east side near the ruins of a columbarium. Immediately behind the latter the top of the stratified clays was determined as $66\frac{1}{2}$ metres, a figure agreeing remarkably closely with the majority of the maximum heights farther north. Still higher up, however, are other clays, which, while similar in general appearance, are either very irregularly bedded or altogether unstratified. The upper limit of these clays was found to be 82·76, or, say, 83 metres. While these highest beds may possibly have been deposited by the waters of springs issuing from faults and fissures (the line of disturbance mentioned in a previous chapter passes through the Gorn at this point), one must, in the absence of any definite evidence to the contrary, regard them as probably representing the extreme marginal deposits of the lake.

We may, indeed, conclude that, while the lake presumably at one time reached to a maximum level of 85 metres, it stood for a considerable period at about 70 metres above sea-level.

The next step was to ascertain the altitudes of the archæological sites and the relation of the latter to the lacustrine deposits. Up to the present time levels have not been carried through to the south end of the oasis, and aneroid determinations are not of sufficient accuracy for our purpose, so that we must confine our attention in this connection to the northern portion of the depression. The ground-level of the temple of Hibis was found to be at 75 metres and the lowest of the tombs of the Necropolis at 80·6 metres above sea-level. The columbarium already alluded to, on the south-east side of the Gorn el Gennâh, is built on the denuded slopes of the lacustrine series at a level of 57·2 metres, while the base of a number of brick ruins a little to the north was found to be just over 53 metres. Finally, the ground-level at the base of the slope on which stands Qasr Zaiyan was determined as 21 metres, a bench-mark being made on the southern door of the temple at 24·52 metres above sea-level.

There are several points in connection with the disposition of the archæological remains which cannot but strike one. In the first place, they are mostly on or near the extreme margin of the lacustrine deposits; secondly, they are absent altogether from the central portion of the lake site; and thirdly, the older monuments occupy the highest levels, while there are no representatives at all of the earlier Egyptian periods. While the disposition of the monuments may, of course, be entirely fortuitous,

we are justified, I think, in assuming that the lake existed well into the historic period, and may have still stood at the 65 or 70 metre level when the temple of Hibis was erected by Darius, about 500 years before the commencement of the Christian era. In the time of the Ptolemies it was certainly considerably lower, while in still later days, when the country became a Roman province, the lake had very much contracted, and probably only existed as a marshy swamp occupying the lower portions of the depression.

What age, it may be asked, is indicated by the pottery, bones, and fresh-water shells which, as already mentioned, have been found in the lacustrine deposits? Unfortunately the shells belong to species which have a wide distribution, and have persisted from early Pleistocene times right up to the present day. They do not, therefore, help us to fix the age of the deposits, except within wide limits. The bones were submitted to Dr. Andrews, F.R.S., of the British Museum Staff, and his conclusion is that they belong to two domesticated animals—one a small, lightly-built ox, the other a small horse, donkey, or zebra; unfortunately they are not sufficiently complete to be determined with certainty. Finally, as to the pottery: the types do not differ in any important respect from those associated with the towns and cemeteries of Græco-Roman age in many parts of the oasis. The barrel-shaped pot has, indeed, persisted to modern times, being, in a slightly different design, the standard

water-jar at the present day in the oasis of Dakhla. The pottery, therefore, bears out our conclusions that the lake continued to exist well into the historic period.

Although flint implements have never yet been detected *in situ* in the lacustrine deposits, I have collected a considerable number from the area originally occupied by the lake. Some of these were found lying on the denuded surfaces of the lake beds, in positions which lead me to suppose that they have weathered out from the deposits. They are decidedly Neolithic in workmanship and character, and were, in my opinion, used by people inhabiting the depression at the time of, and probably prior to, the existence of the lake. A number of examples are shown in one of the accompanying plates; the figure in the bottom left-hand corner is, however, that of a palæolith, a typical example of those which occur on the borders of the plateau, and on or near the eastern escarpments. In the right-hand bottom corner is figured an object of very common occurrence in the oasis—a sandstone hand-grinder, probably of Roman age. With the exception of these two the specimens illustrated are all implements from the site of the lake. Flint implements were evidently in use in Kharga at a very late period, as large numbers of worked flints, mostly in the form of flakes or tools of very poor finish, occur near many of the old sanded-up wells. A considerable amount of detailed work will have to be undertaken before the different flints of the

oasis can be satisfactorily arranged in chronological order.

From what period did the lake date, and to what cause did it owe its origin, are questions which cannot, I fear, be definitely answered as yet. While it is quite reasonable to consider, in the absence of any decisive evidence to the contrary, that the lake originated in early prehistoric or Pleistocene times —that it dates possibly from the time of the formation of the tufas of the Nile Valley and oasis-escarpment, when the climate was certainly much moister than at the present day—we must not forget the possibility that it was formed by artificial means during one or other of the Egyptian dynasties between 3000 and 1000 B.C.

There is good reason to believe that the depression was inhabited previous to the formation of the lake, and although we have no information as to when the first deep borings were made, there is some evidence which leads me to suspect that wells existed prior to the time when the surface of the lake began to fall, if not very much earlier. The evidence to which I refer is the discovery of a portion of an earthenware pipe embedded *in situ* in the lake clays at a height of 42·85 metres, of the type used by the ancients for lining their water-channels. Is it possible, therefore, that, as the result of the industry of the ancient well-borers—following their initial discovery of these deep-seated sources—the long-confined waters welled up with irresistible force, and gradually flooded the

country. At the present day, when the pressure throughout the artesian basin must be very much less than formerly, it is not uncommon for new bores to get out of control and flood considerable areas of country. The same thing may possibly have happened on a very much larger scale thousands of years ago, when the first bores were sunk into a previously untapped artesian basin, fully charged with water under great pressure.

There is another explanation which it is advisable to keep in mind, though it has never hitherto, as far as I am aware, been advanced as a possible cause of the formation of lakes. The very existence of artesian water depends on the presence of porous strata overlain by impermeable beds. If one or other of the porous beds, charged with water under pressure, should, through the action of denudation on the overlying beds, become exposed at the surface, the waters would escape through natural springs in very large quantities. This might, indeed, continue for a long period of time, until the bed was nearly depleted and the pressure reduced to nil. There is little doubt that the beds which we have named the 'Surface-water Sandstone,' and which are now exposed in places on the floor of the oasis, were originally entirely covered by impervious clays, and contained artesian water under pressure; they may, in fact, have been in the same condition as is the Artesian-water Sandstone at the present day. It is conceivable, therefore, that when those beds became exposed at the surface, owing to the

removal of the overlying confining strata, their contained waters escaped in such quantities as to have given rise to a lake of considerable dimensions, if not to one equal in size to that which we have been considering.

No one can be more conscious than myself of how much there is still to be learnt regarding the topographical aspects of the oasis in early historic times, and although the theory that the lake may have been formed by waters which escaped from the underlying water-charged beds (either artificially through bore-holes or naturally as springs) may at first sight appear fanciful, it is one which, in the present imperfect state of our knowledge, is at least worth bearing in mind. A more detailed examination of the lacustrine deposits would probably throw further light on the matter; and a minute analysis of the nature, composition, and arrangement of the individual grains would almost certainly show whether the beds have in the main been formed of sediment carried into the lake by streams from the neighbouring cliffs and plateaux, or whether they represent wind-borne accumulations of sand and clay-dust from the surrounding plains.

At whatever period and in whatever manner the lake may have been formed, it is quite clear that it existed well into historic times, and that on its bed were laid down thick deposits of clay and sand, which at the present day form the bulk of the cultivated lands of the oasis.

CHAPTER IX

THE UNDERGROUND WATER-SUPPLY

The Water-bearing Strata underlying the Libyan Desert—Essential Conditions required to produce an Artesian Basin—The Surface-Water Sandstone—Collecting Pits—Fissures—Yield of Water—Flowing Wells from this Sandstone—Bores at El Dêr el Ghennîma—Variable Quality of Water—Ancient Subterranean Aqueducts—The Artesian-Water Sandstone—General Characters—The Headquarters Area avoided by the Ancients—Drilling Difficulties—Results of New Bores—Factors determining Discharges of Wells—Temperature and Chemical Composition of Artesian Waters.

When laboriously traversing the hot and arid plateaux of the Libyan Desert, our thoughts divided between the fertile plains of the Nile we have left behind and the still far distant oasis, it is difficult to realize the presence, within a distance of a few hundred yards, of an abundant supply of the purest water. Yet there is little doubt that the water-bearing beds underlie practically the whole of the Libyan Desert, though it is only on the floors of the depressions that they lie within accessible distance of the surface. On the high tablelands the cost of sinking bores to reach the sandstones would be prohibitive, and without the aid of powerful and costly pumps the water would not rise to the

level of the ground. But although the subterranean waters of the great desert plateaux cannot economically be made available at the surface, it must not be forgotten that the deeply buried sandstones of these regions must act to a great extent as storage reservoirs capable of replenishing the beds underlying the oases-depressions, from which large volumes of water are continuously drawn by the numerous artesian wells.

The essential conditions required to produce an artesian basin, which, when tapped by borings, will produce self-flowing wells, are the presence of strata of sufficient porosity to carry water, enclosed above and below by beds of sufficient impermeability to prevent the escape of that water; the outcrop of the porous beds in some higher and distant region, with an adequate exposure to an abundant source of water, whether rain, river, or lake; and, finally, the absence of an easy escape at a lower level, unless at a considerable distance from the sites of the wells.

These requirements are well fulfilled in the Libyan Desert, where the Nubian Series at the base of the Cretaceous consists of highly porous sandstones, subdivided by impervious beds of shale, overlain by a great thickness of absolutely water-tight beds, and underlain by probably almost equally impermeable crystalline rocks. These porous sandstones rise gradually to the south, and presumably outcrop in Nubia and the Sudan, though whether, as we shall see later, they derive

their water-supplies from the Nubian reaches of the Nile, from the great swamp regions of the Sudan, or from the rains of Abyssinia or Darfur, is still, to some extent, an open question.

In Northern Kharga we find two similar but distinct sandstones, separated by a 75-metre band of Impermeable Grey Shale. The upper bed, which we have for convenience designated the 'Surface-water Sandstone,' is exposed at the surface, and contains standing or sub-artesian water; while the lower, from which the flowing wells derive their supplies, never approaches within 80 metres of the surface, and forms the true 'Artesian-water Sandstone.' It will be convenient to give these sandstones separate consideration.

The Surface-Water Sandstone.

The stratigraphical position of the Surface-water Sandstone will be seen by reference to the geological sequence given in a preceding chapter, and to the section drawn across the oasis. The beds forming this division have an average thickness of 45 metres, and consist almost entirely of fine sandstones or coarser grits, often containing an abundance of oxide of iron, and occasionally beds of alum and Epsom salts, or, to be chemically exact, hydrous sulphates of alumina and magnesia. Thin bands of shale are frequently met with, intercalated in the sandstones, generally near the top or base of the series. On the level or gently undulating floor of

the oasis, to the east of the line of disturbance passing through Jebel Têr, the Surface-water Sandstone has a wide outcrop, while to the west, where the general level of all the formations is higher, the same stage forms the foot-hills of Jebel Tarif, of Jebel Têr, and of the high cliffs which rise to the north of Um el Dabâdib and Ain Lebekha. It is probable, moreover, that the sandstones which form the surface of the desert between Kharga and Dakhla, and which cover immense areas to the south of the oases, also belong to this group.

Over a portion of the floor in the north of the depression these sandstones have been entirely removed by denudation, so that in this area the underlying grey shales form the desert surface. At one time the sandstone was continuous across the depression, and entirely covered by an impervious mantle consisting of the Purple Shales. It was then, in all probability, fully charged with water under pressure, as is the true Artesian-water Sandstone at the present day; and it is possible, as we have already suggested, that when the sandstones in question were first laid bare by the active agents of erosion, innumerable springs broke forth, and gave rise to a lake of considerable magnitude, which may, indeed, have been that which persisted into the historic period.

In the district round Headquarters several pits have been sunk in this sandstone, from which the water is lifted by power for purposes of irrigation. In six pits the maximum level of the water

varies from 55·38 to 56·52, the average being 55·74 metres. From Headquarters the general surface of the country falls to the north, south, and east, and curiously the water-level in the sandstone falls in the same directions. In a pit near Bore No. 43, about 3½ kilometres to the south-west, the water-level is 52·4 metres; at points 640 metres and 2 kilometres to the west it was found to be 52·16 and 50·21 metres respectively; while near Bore No. 33, 4 kilometres to the north, the surface-water stands at 52·71 metres above sea-level. The ground-levels at these points are 54·54, 57·90, 53·61, and 57·61 respectively, while that at Headquarters averages 59·57 metres above sea-level.

For irrigation purposes an ordinary bore-hole or small pit is quite useless, the inflow of water through the pores of this sandstone being too slow to yield a pumping supply. When a large pit is excavated, fissures, through which water is seen to be freely circulating, are nearly always exposed. Experiments show that—provided a sufficiently large collecting-tank is made, measuring, for instance, 5 by 4 metres, and sunk from 1 to 2 metres below the standing water-level—a supply sufficient to yield a continuous discharge of 8 gallons a minute (equivalent to 11,500 gallons per day of twenty-four hours) can frequently be obtained. Moreover, by sinking a bore to a depth of 7 or 8 metres from the bottom of the pit, preferably on one of the fissures, the supply can be increased threefold, the water emerging from the bore in considerable volume, though

with insufficient pressure to carry it (in a length of well-casing fixed on the top of the bore-hole) above the level of 55·74. The latter figure may, indeed, be regarded as the static head in this neighbourhood of the water in the Surface-water Sandstone. The fact that from this sandstone we are unable to obtain an artesian well at the surface, but can get flowing water at a depth of a few metres, is an important illustration of the very slight difference in some cases between flowing and non-flowing wells, and of their close connection with, and dependence on, the absolute ground-level.

The extent to which this sub-surface source can be drawn on without lowering its level has not yet been determined, though, in a pit alongside Bore No. 2, a 'saqia' or Persian waterwheel (a native contrivance adapted for lifting water, worked by oxen or camels), has been working for about eighteen months without appreciably affecting the supply.

We have seen that a flowing well can be obtained (in a pit) a few metres below ground-level, and under certain conditions it may be possible to obtain flowing wells at the surface from the sandstone under consideration; the occurrence of artesian water at El Dêr el Ghennîma, on the east side of the depression, may, indeed, be a case in point. To the east of Headquarters, as may be gathered from the section, the Surface-water Sandstone dips gently under the Purple Shales, the thickness of the latter increasing as the eastern escarpment is approached.

Running north and south through El Dêr is an anticlinal fold, and flowing water is obtainable from wells sunk on its crest through the shales to the underlying sandstone. The original depths of the ancient wells in this district cannot be determined with certainty, but when one of those to the north of the ruined fort was cleaned out and cased, flowing water was obtained when the drill reached a depth of 41 metres. Below this the ground appeared to be untouched, the bore being carried a few metres deeper into fresh sandstone, which yielded an increased supply. This well has given a steady discharge of about 40 gallons a minute for over eighteen months. Quite recently the flow has been augmented to just over 50 gallons per minute by its outlet being lowered about $1\frac{1}{2}$ metres, to $92\frac{1}{2}$ metres above sea-level.

The water here seems to be derived from the Surface-water Sandstone, though, considering that the well is situated on a line of folding, it would not be advisable to entirely disregard the possibility of the presence of fissures, through which the water might rise directly from the Artesian-water Sandstone below. If, as appears to be the case from the depth and position of the bore, the water does have its origin in the Surface-water Sandstone, the explanation may be that the necessary working head or pressure is furnished by the difference of level of the sandstone here and in adjacent districts. In the extreme north of the oasis the same sandstone lies at a considerably higher level, and, at the same

time, holds large volumes of water, and it may be that the pressure of this water, acting on that contained in the beds at lower levels, gives rise to flowing wells when bores are sunk in favourable localities.

A very great drawback to the water of these upper sandstones is its variable quality. In the Headquarters district it is usually more or less ferruginous, and in some pits may contain as much as 63 grains of dissolved solids per gallon, the salts consisting of iron, potash, and soda, with traces of lime and magnesia, mostly in the form of sulphates and chlorides. Mr. William Garsed* has calculated that this water would, if used for irrigation at the rate of 3 gallons a minute per acre, effect an annual deposition of over 3 tons of sulphate of potash and common salt on each acre of land. Salts of this nature in such quantities would, of course, have a very deleterious effect on the crops, not to mention the mechanical binding action of the iron on the soil.

It appears that the want of uniformity in the quality of the water is due to local causes, chief of which may be the relative abundance of fissures, the purity of the sandstone, and the presence or absence of mineralized shales. In those areas where the water is moving only slowly—where, in fact, it

* I should like to record my indebtedness to Mr. Garsed, who, while in the oasis, undertook, at my request, a considerable amount of special analytical work, in addition to his regular duties.

tends towards stagnation in the strata—it is probably liable to become more or less highly charged with mineral salts; certainly the best qualities seem to coincide with relative abundance, and the largest supplies are undoubtedly found where the beds are traversed by fissures.

In many parts of the oasis perfectly sweet water is obtainable from the sandstones of this series, and this source, as an auxiliary to the artesian supplies obtained from deep borings, was taken full advantage of in olden times. The ancients constructed the most marvellous systems of subterranean aqueducts to tap these sources, more especially in the neighbourhood of Um el Dabâdib, Qasr Lebekha, and Qasr Gyb, where such works were especially applicable, owing to the fact that the sandstones in those districts form extensive hills above the general level of the surrounding cultivable ground. These underground works are, in many respects, of far greater interest than the ancient monuments, and they will therefore be fully described in a later chapter.

The Artesian-Water Sandstone.

The source of the great majority of the flowing wells of the oasis is the group of sandstones underlying the Impermeable Grey Shales. Although the beds of the series are nowhere visible to the eye, their general characters can be judged by an examination of the material brought to the surface during drilling operations. The samples prove

that, in general lithological characters, the Artesian-water Sandstones do not essentially differ from those just described. Throughout the area over which boring operations have recently been carried out no well-defined, continuous, argillaceous bands have been met with, though lenticular intercalations of clayey strata are not uncommon. Up to the present time the base of the Artesian-water Sandstone has not been reached, although the deepest borings have been carried down to a depth of 122 metres below its junction with the confining shales above. The different bands vary considerably in coarseness and porosity, in hardness, and in the amount of cementing material between the individual grains of the rock, all of which characters have a marked influence on their capacity as water-carriers. Judging from their unfossiliferous nature, from the presence of thin seams of lignite associated with bands and nodules of iron pyrites, and from certain other considerations, we are led to infer that these sandstones were originally laid down on the bed of an immense inland fresh-water lake.

During the past half-century the natives have put down a considerable number of deep bores in this and the neighbouring oasis. No written records concerning these are, however, available, so that in seeking information one has to rely on the memory of the men who sunk the wells. By careful cross-questioning I have collected a large amount of interesting and valuable information, but still, in

describing the artesian wells themselves, it will be more satisfactory to confine our attention to those which have been drilled on the Headquarters area during the last two or three years, and of which accurate and reliable records have been preserved.

The Headquarters area, occupying the central part of the depression between Kharga village and Jebel el Ghennîma, is one of the few large districts entirely devoid of old wells and traces of former cultivation. A combination of unfavourable circumstances appears to have led the ancient well-borers to avoid this district. Firstly, the general elevation is comparatively high, meaning small flows from wells of ordinary depth; secondly, the superficial alluvial deposit is clayey and heavy, necessitating a considerable expenditure of time and labour to bring it into satisfactory condition for cultivation; and, thirdly, and probably most important of all, the presence of a copious supply of sub-surface water, which would have greatly hampered, if not made impossible, the sinking of wells by the ancient system.

It may therefore be assumed that, owing to the entire absence of both ancient and modern wells, the sandstones of this district were practically fully charged with water at the time the first bore was sunk.

The junction of the Artesian-water Sandstone with the grey shales above is usually fairly abrupt, the first flowing water being obtained as soon as the

drill strikes the top of the sandstone. Where alternating sandstones and shales occur at or near the junction, the former are generally charged with water under feeble pressure, yielding flows at the surface of from 1 to 5 gallons a minute. Sometimes, indeed, the piercing of these thin bands, prior to the main body of sandstone being entered, merely results in a rise of water in the bore-hole, without actual flow. On drilling into the sandstone proper, increments of the flow are obtained at fairly frequent, though irregular, intervals of depth. At times the discharge is seen to increase slowly but steadily, while a particularly porous bed is being passed through; at others the rate of increase is so rapid as to suggest that a fissure charged with freely flowing water has been struck. As a rule, hard beds of sandstone, (the 'shells' of American drillers) overlie the best water-carrying layers, and though these act locally as confining beds, there almost certainly is, nevertheless, an intimate connection between different parts of the sandstone, as no persistent argillaceous bands have been met with.

Loose uncemented sands may be encountered at any time, but do not seem to coincide with marked increases of flow. These 'quicksands' form one of the greatest difficulties with which drillers have to contend, and many bores have perforce to be discontinued owing to the impossibility of drilling through them. The loose sands 'cave'—that is, run in from all sides—the whole wall of the bore

at times falling in, throughout a length of 5 or 10 metres. The only remedy against caving is the insertion of casing, but this is generally undesirable, as it may effect the shutting off of water already obtained from the upper bands of the sandstone; in some cases, however, perforated lining may be satisfactorily employed.

Of thirty-one bores finished in this district, none has failed to strike water, though three have yielded such small flows that they may be regarded as comparative failures. The average flow of the thirty-one wells, the measurements being made in each case a week or two after completion, was approximately 100 gallons a minute, the maximum being 315 and the minimum 18 gallons per minute. All bores have shown a marked decline in discharge for some time after completion, when, if isolated, they have settled down to a fairly steady flow, or at least to a flow which decreases at a constantly diminishing rate.

Owing to the very adverse effect of some of the larger bores (situated on the lower parts of the area) their flows have been purposely reduced; and as a further precaution against over-exploitation, and as a remedy to the waste consequent on irrigation at night, all wells are, as far as possible, shut down between sunset and sunrise. The average discharge, therefore, at the present day is considerably less than the figure mentioned above, amounting, in fact, to approximately 70 gallons a minute per bore.

By far the most important factor determining the volume of flow is the absolute ground-level at the mouth of the well. The floor of the oasis in the district in question lies between 53 and 61 metres above sea-level, the general slope being to the west, in the opposite direction to the dip of the water-bearing sandstones. Although the actual difference of level is so little, amounting only to 7 or 8 metres, the difference of flows from wells of equal depth on either side of the area averages fully 100 per cent. This indicates that the surface of this area is very near the static head or limit to which water will rise from bores of this depth; in fact, if the ground were raised by a very few metres, not one of the wells would discharge at the surface. This I have proved by actual experiment, and it is, moreover, borne out by the observed pressure, which even in the best wells seldom amounts to more than 13 or 14 pounds to the square inch.

Before going further into this important matter of pressure, let us briefly notice the temperature and chemical composition of the artesian water. In Dakhla Oasis the temperature of the wells often rises as high as 90° or 95° F., the highest recorded being 105° F. in Bir el Dinaria, a bore sunk fifteen or sixteen years ago, and the deepest and most northerly in that oasis. In Kharga it is seldom that we meet with temperatures over 90° F., the well-waters at Headquarters varying from 86° to 88° F. Identical figures were obtained in the southern part of the oasis.

One of the most noticeable features of the artesian water is its highly effervescent character when it reaches the surface. In most of the newer bores the water is so strongly charged with minute bubbles of gas that it closely resembles the contents of a newly-opened bottle of highly aerated water, while in many of the older wells the gas rises to the surface in a slow procession of large bubbles.

Analysis shows the gas to consist almost entirely of nitrogen, only small quantities of oxygen and carbon dioxide being present; and it has been estimated by rough experiment that the volume of gas issuing from Bore No. 1 (internal diameter, $4\frac{1}{4}$ inches) amounts to half a pint per minute. My own opinion is that this nitrogen represents ordinary air deprived of its oxygen during the underground passage of the water, and this explanation seems confirmed by Mr. Lucas, F.C.S., Chemist to the Egyptian Survey Department, who refers me to several cases in which air is believed to have been depleted of its oxygen by pyrites, etc., during its passage underground.

The quality of the artesian water is in all respects excellent, and when taken direct from a cased well forms, after cooling, a palatable water free from all danger of contamination. Analyses by Mr. Garsed of water samples from four bores show the total dissolved solids to range from 43 to 47 parts per 100,000, equivalent to from 30 to 33 grains per gallon. In new bores the water is usually only slightly ferruginous, though, as already mentioned,

in some of the ancient wells of certain districts it is so highly charged with ferric oxide that thick deposits of ochre have been formed along the irrigation channels.

The chemical composition of the dissolved salts, so far as determined, is shown in the following table:

ANALYSES OF TYPICAL ARTESIAN WATER OF KHARGA OASIS (HEADQUARTERS DISTRICT).

	Bore No. 1.	Bore No. 2.	Bore No. 5.	Bore No. 6.
Total solids (grains per gallon)	33	30	33	32
Composition of dissolved salts, per cent.				
Silica	4·2	4·5	4·6	3·4
Ferric oxide ...	1·7	0·8	1·2	1·3
Lime	6·5	7·0	5·4	5·6
Magnesia	2·9	3·1	2·7	3·8
Sulphuric anhydride	4·5	4·9	4·4	4·4

CHAPTER X

FLOWING WELLS: SOME EXPERIMENTS AND OBSERVATIONS

Total Water Discharge of Oasis—Water-Pressures—Static Head—Importance of Systematic Observations and Records of Bores — Sensitiveness of Wells — Experiments showing Mutual Interference of Wells—Bores Nos. 5 and 6—Bores Nos. 4 and 42—The Wells at El Dêr el Ghennîma—Decline in Discharge of New Wells—Effect of Closing Bores—Rate of Flow of Water in Sandstones—Danger of Over-Exploitation — Holding Capacity and Porosity — Experiments on Porosity of Nubian Sandstone—Large Quantities of Water held in Storage Beds—Economically only partially available at Surface.

At the present day there are about 230 native-owned wells in the oasis, yielding a total discharge of some 295 qirats. We have seen that the qirat has not a fixed value, but represents a discharge varying from 22 to 38 or more gallons a minute. Applying these values as far as possible to the old wells, and adding the known discharge of the new, we shall not be very far from the truth if we estimate the total discharge of the oasis wells at 8,000 gallons a minute, or 11,500,000 gallons (53,000 cubic metres) a day. The largest well in Kharga Oasis is Ain Estakherab at Gennâh, with a discharge of between

700 and 800 gallons per minute. The average yield of those which might be described as the best wells probably does not exceed 150 to 200 gallons, while there are a great many which only discharge 20 or 30 gallons per minute.

In some parts of the world the discharges of artesian wells are measured by thousands, not hundreds, of gallons. In Queensland and other parts of Australia, for instance, there are numerous bores throwing over 1,000 gallons a minute; in these regions the depth of individual bores in many cases amounts to thousands of feet, the pressure frequently rising as high as 100 pounds to the square inch. It must, moreover, be borne in mind that the artesian basins of Australia have only been exploited during a comparatively short period, and that from the nature of the country the wells are, as a rule, at considerable distances apart.

The exploitation of the artesian basin of the Libyan Desert has been in progress for hundreds and thousands of years, and it is probable, therefore, that in the oases-depressions the general average pressure has been very much reduced. At the present time the water-pressures seldom exceed a very few pounds per square inch, so that the static head, or absolute height to which the water will rise, is seldom more than a few metres above the actual surface of the ground. The outlets of the native wells are, unfortunately, of such a nature that it is not possible to make even approximate determinations of pressure; but after taking into

account the influence of ground-level on the volume of flow, we still find differences which point to there being considerable variation in the absolute static head in different parts of the oasis—that is to say, the water will rise higher in some places than in others. This is probably partly to be accounted for by variations in the level of the underlying strata and by the presence of faults—for instance, the static head to the west of the central line of disturbance is certainly considerably higher than to the east.

In the absence of accurate data, the static head in a district can be approximately gauged from the ground-level and flow of any one of the higher and more isolated wells. The maximum static head judged in this way appears to be 88 metres above sea-level in the Kharga district on the west side of the fault; but in the Headquarters area, to the east of the fault, it can be definitely proved to be very much less.

In order to determine the extent of the local variations throughout the district where the recent boring operations have extended, I carried out a number of experiments. For this purpose four bores in different parts of the area were selected, of similar diameters, and of approximately equal depths into the water-sandstone. By means of a flange the casing of each bore was carried vertically upwards, the ordinary outlet being kept shut until the pressure ceased to rise, as indicated by a pressure-gauge. It was then found that in Bore

No. 36 the water had risen to 61·6 metres, in Bore No. 38 to 59·55, in Bore No. 42 to 64·26, and in Bore No. 44 to 62·0 metres above sea-level. The average static head in this district may therefore be taken as 61·85 metres. The positions of the four bores in question, with regard to Headquarters, are as follows: No. 36, 7·7 kilometres N.; No. 38, 2·6 kilometres N.W.; No. 42, 1·6 kilometres S.E.; and No. 44, 3·9 kilometres W.N.W.

To the north of Meheriq the static head appears to rise, as flowing wells are found up to 76 metres above sea-level (Ain Mohammed Delaib). The water-level at Ain el Ghazâl is even higher (84·56), but this well does not actually run.

In the development of an artesian basin this question is of the utmost importance; only by a knowledge of the static head and the ground-level can we, with any likelihood of success, estimate beforehand the discharge to be looked for in any particular district. If, for instance, we sink a bore in a locality whose surface is above the static head, the result, so far as a flowing well is concerned, can only be failure, however great the amount of water existing in the underlying strata. If a sufficient number of observations are available, it is possible to construct charts showing the isopotential lines, or lines of equal pressure, and these may be of great value when boring is contemplated in intermediate districts.

It is seldom that accurate records of bores are preserved in the initial stages of the development

of new artesian basins, and to this neglect is due much of the doubt which frequently arises at a later period as to the extent and permanence of the underground water-supplies.

In some countries, however, the water-resources have long been the subject of exhaustive examination, notably in the United States, where a most valuable and instructive series of water-supply reports has been issued by the Geological Survey. The chief difficulties arise from the fact that bores are generally the property of private individuals, who are seldom both able and willing to supply accurate information. Discharges, for instance, are usually given in the roundest of figures, and without regard to the conditions under which they were taken. In Australia more than one geologist has called attention to the matter, and quite recently Mr. G. H. Knibbs, F.R.A.S., of the University of Sydney, in a valuable and suggestive paper on the hydraulic aspect of the artesian problem, refers to the want of comprehensive and deliberate investigation in the past, and admits the inadequacy of the available data for the determination even of the one question only—*i.e.*, the extent to which exploitation can be pushed without fear of exhausting the supply.

When drilling was first commenced in the Headquarters area, the bores were placed at an average distance apart of 500 metres; circumstances, however, led to there being a considerable variation in the depths of the wells, with the result that those of

shallow depth and those situated on comparatively high ground were adversely affected by the deeper and more favourably placed bores. The sensitiveness of any one well to the influence of its neighbours is, I believe, far greater than is generally supposed, and appears to be especially dependent on the amount of difference between the depths, discharges, and surface-levels of the bores. In investigating this subject I made a number of experiments with the object of determining the mutual influence of wells, and perhaps some reference to these may not be without interest and value.

The first experiment to which I shall refer was made on wells situated comparatively close together. Bore No. 5 is 570 metres W.S.W. of Bore No. 6, the outlet of the former being at 57·38, that of the latter at 59·18, a difference of 1·8 metres. No. 5 has an internal diameter of $5\frac{5}{8}$ inches, is 197 metres deep and 95 metres into the water-sandstone; No. 6 has a diameter of 8 inches, is 146 metres deep, and 61 metres into the sandstone. The two wells had been flowing continuously for a considerable period, and during the experiment neighbouring wells were kept shut down, so that there is no reason to suppose that the observations were affected by other bores.

Bore No. 5, discharging 114 gallons a minute, was shut down at 7 p.m. on June 12, 1907, and reopened at 7 a.m. on June 13. The hourly observations, as given in the following table, show the effects produced on Bore No. 6.

EXPERIMENT TO SHOW MUTUAL INTERFERENCE OF BORES.

Bore No. 5 closed at 7 p.m., June 12, 1907.				Bore No. 5 opened at 7 a.m., June 13, 1907.			
Time.	Discharge of Bore No. 6.	Time.	Discharge of Bore No 6.	Time.	Discharge of Bore No. 6.	Time.	Discharge of Bore No. 6.
P.M.	Gallons per Minute.	A.M.	Gallons per Minute.	A.M.	Gallons per Minute.	P.M.	Gallons per Minute.
7.0	61·2	1.0	76·6	7.0	83·7	1.0	69·0
8.15	65·6	2.30	77·4	8.0	78·4	2.0	67·7
9.0	68·4	3.0	79·2	9.0	75·0	3.0	66·8
10.0	69·6	4.0	79·7	10.0	73·0	4.0	66·2
11.0	73·2	5.0	82·1	11.0	70·8	5.0	66·6
12.0	74·7	6.0	83·1	12.0	69·6	6.0	65·3
						7.0	64·0

From these figures it will be seen that the shutting down of a flowing or the opening of a closed well may produce a most marked effect on a neighbouring well within the short space of sixty minutes, even when the intervening distance is over 500 metres. In the above instance the rate of increase was most rapid at first, there being a gain of 7 gallons per minute, equivalent to about 12 per cent., in the first two hours. The total increase in the twelve hours amounted to $22\frac{1}{2}$ gallons, or about 37 per cent. On reopening No. 5 it is seen that the discharge of No. 6 at once commenced to fall, the loss being nearly 9 gallons in the first two hours; afterwards the rate of decrease gradually diminished, until at 7 p.m., when the observations were discontinued, the flow had fallen to within 3 gallons of its normal.

A second series of observations was made between

two bores considerably farther apart, No. 4 being 835 metres N.N.W. of No. 42. The difference of level in this case was found to be 1·18 metres, the outlet of No. 4 being 60·74, and that of No. 42, 59·56 metres. Bore No. 4 has an internal diameter of $4\frac{1}{4}$ inches, is 141 metres deep, and draws from 19 metres of sandstone; Bore No. 42 is 6 inches in diameter, 218 metres deep, and 69 metres into the water-sandstone. Previous to the experiment, No. 4 was flowing 36·75, and No. 42 about 68·5 gallons per minute. Precautions were taken against other wells influencing the results, the nearest bores having been opened twenty-four hours previously and being kept in the same condition throughout the experiment. Bore No. 42 was closed down at 9 a.m. on March 4, 1908, periodical observations being then made of the discharge of No. 4 during the next thirty-six hours.

Briefly stated, the result of this experiment was as follows: The discharge of No. 4 had not perceptibly increased at the end of the first half-hour, but had done so after one hour. It continued to increase at a very slow rate, the net gain after thirty-six hours being only 3 gallons, or between 8 and 9 per cent. In this case the mutual interference is very much less than that between Nos. 5 and 6, doubtless largely owing to the greater distance apart, and to the lesser difference between the outlet-levels of the wells. In all probability there are many other conditions which combine with the above in determining the amount of interference,

such as the positions of the wells with regard to the main lines of underground flow, the relative depths of the bores, and the thicknesses of sandstone from which they draw their supplies.

The most marked example of interference with which I have met was in the case of two ancient wells at El Dêr el Ghennîma, situated only 88 metres apart, on the crest of an anticlinal fold running north and south. These wells had been sanded-up for centuries, but were recently taken in hand and cleaned out. The difference of level in the outlets is 2·07 metres, the higher well being 34½ metres in depth, the lower 41 metres. The opening or closing of the lower well produces an almost instantaneous effect on the higher, the difference in flow of the latter within thirty seconds amounting to as much as 11 per cent.

A great many observations were made, but the following are sufficient to show the rates of decrease and increase:

	Gallons per Minute.					
Upper well flowed	13·2	when lower well was open (flow 50·3 g.p.m.).				
,, ,,	20·5	,, ,,	had been closed 10 minutes.			
,, ,,	23·7	,, ,,	,, ,,	20	,,	
,, ,,	26·3	,, ,,	,, ,,	30	,,	
,, ,,	39·4	,, ,,	,, ,,	24 hours.		
,, ,,	35·6	,, ,,	had been open	30 seconds.		
,, ,,	32·5	,, ,,	,, ,,	2 minutes.		
,, ,,	26·7	,, ,,	,, ,,	7	,,	
,, ,,	24·9	,, ,,	,, ,,	9	,,	
,, ,,	23·4	,, ,,	,, ,,	16½	,,	
,, ,,	19·7	,, ,,	,, ,,	45	,,	

The closing down of the lower well is thus seen to have influenced the discharge of the upper to

the extent of 100 per cent. in the short space of thirty minutes, while the flow was trebled in twenty-four hours. On opening the lower well the discharge of the upper fell to within 50 per cent. of its normal within forty-five minutes.

As already mentioned, most bores show a marked decline in discharge for some time after completion, and except in special cases it seems doubtful if large bores can be expected to maintain their original flows for long periods of years. During the early part of its existence a well draws its supplies from fully saturated beds, the water being forced into it from every side, not only through the pores of the sandstone, but through any fissures the bore may have struck. The flow of water through a compact sandstone is, however, extremely slow, and it is probable that as time goes on every bore becomes more and more dependent on fissures for the maintenance of its supply. This supersaturation of the water-bearing beds, if we may be permitted to use the term, is well illustrated by the closing of a bore for a few days. The water at once commences to accumulate around it, and when the bore is reopened the discharge will generally be found to have increased to a very great extent. As an example of this I may mention Bore No. 14, which, on April 19, 1907, was flowing at the rate of 225 gallons per minute. The well was then closed down for five days; on reopening the discharge was found to be 370 gallons per minute, an increase of 145 gallons, or about 65 per cent., the pressure

during the same time having risen from below 9 to nearly 16 pounds per square inch. The discharge took about twelve hours, or one-tenth of the time, to fall to its normal. On another occasion the same well had its output increased from 217 to 339 gallons by being closed for twenty-four hours, a gain amounting to 55 per cent.

The rate of flow of water through an underground sandstone depends upon a number of conditions, the most important being the size of the pores or spaces between the component grains, the porosity or water-holding capacity of the sandstone, the temperature of the water, and the pressure acting on it. The yield of a well will depend, of course, not only on all these factors, but also on the diameter of the bore, its depth into the water-stratum, the size and number of fissures passed through, and, last and most important of all, on the absolute height of its outlet. Large pores, high average porosity, and high temperatures make for strong flows, though in the absence of pressure greater than that due to a column of water equal in height to the distance between the water-stratum and the outlet of the well, they are in themselves of no avail in the production of an artesian flow. Moreover, although some of the above conditions may be known beforehand, the resistance to flow of the strata immediately surrounding a bore can never be more than approximately conjectured, as the size and mode of arrangement of the individual grains of any sedimentary rock must always vary,

both horizontally and vertically, to a very great extent, and on these factors depends in very large measure the capacity of the strata to transmit water.

Data are as yet far too insufficient to warrant an attempt to calculate the supply which can safely be drawn from a given area without unduly reducing the pressure, lowering the average static head, and endangering the continuance of the artesian supply. In some parts of the oasis there are bores many hundreds of years old still pouring forth their hundreds of gallons a minute; such wells are probably situated in exceptionally favourable localities, and are very possibly fed to a great extent by fissures. At the same time it must not be forgotten that there are throughout the oasis scores of wells which have ceased to run, either through local exhaustion of the water-bearing strata, or through failure to keep the bore-channels open; possibly through a combination of both circumstances. In some cases time seems to have remedied matters, as it is not uncommon to meet with instances where new bores, sunk in the immediate neighbourhood of long extinct wells, have produced strong discharges of considerable volume.

As I have already stated, the rate of flow of water is largely influenced by both the size of the pores and the porosity of the rock, the capacity to transmit water being very much greater for large than for small pores, and for high than for low porosity. It must, however, be pointed out that large pores and high porosity do not necessarily go

together, and that small pores in a rock frequently accompany high holding capacity. For instance, a fine-grained sample of Nubian Sandstone will absorb from 25 to 28 per cent. of water, a medium-grained sample 20 per cent., while a very coarse sample may take up as little as 15 per cent. The pores and transmitting capacity of the coarse-grained variety will, however, be very much greater than in the case of either of the others.

In order to arrive at some sort of idea as to the holding capacity of the artesian-water strata of the oasis I made an examination of between sixty and seventy samples of sand brought up from varying depths from a few selected bores in the oasis. As, however, owing to the methods of drilling employed, only powdered samples were available, it was necessary in the first instance to ascertain the relative porosity of sandstone in its ordinary state and broken up into the form of sand. For this purpose I collected eight specimens of the Surface-water Sandstone from various points in Northern Kharga, and subjected them to absorption tests, both in the whole and in the powdered states. In six out of the eight examples the absorption was more when powdered than when whole, the average for the eight rock samples being 22·44 per cent.; for the same when powdered, 23·55 per cent. There is, moreover, no reason to suspect that in ordinary lithological characters the Surface-water Sandstone differs in any important respect from the Artesian-water Sandstone, so that if we estimate the porosity

of the latter from powdered samples, we shall obtain a figure only about 5 per cent. too high.

The average porosity of sixty-four samples, collected from Bores 14, 16, 18, 31, 39, and 44, at various depths in the water-bearing strata, was found to be 19·45 per cent. If we confine our attention to a single bore, and examine a representative sample from every stratum of the water-bearing sandstone, and, in deducing the porosity, take into account the thickness of each individual bed, we shall obtain a still more reliable figure. This was done in the case of Bore No. 18, which passed through 122 metres of water-bearing strata, thirty-one samples being collected and subjected to examination. The absorptions obtained varied from 15·3 to 25·5 per cent., the average porosity of the whole column being calculated as 19·6 per cent. I believe this figure may be accepted without misgiving as a satisfactory working value for the porosity of powdered Nubian Sandstone, that of the solid rock being taken as 5 per cent. lower, or, say, 18·5 per cent.

The Artesian-water Sandstone has been proved to reach a thickness of 122 metres, and probably its total thickness is considerably more. Assuming, however, a vertical extent of only 122 metres, the water-bearing beds under 1 square kilometre would, if fully saturated, hold 4,965,000,000 gallons, which is the equivalent of the water which would be discharged in ninety-four years by a well flowing at the rate of 100 gallons a minute. When we con-

sider that the area of the floor of the depression is some thousands of square kilometres, and that the water-sandstones, except in the immediate neighbourhood of the existing wells, are probably fully saturated, we realize the vast amount of water which is stored under the depression alone, irrespective of the still greater quantities which underlie the surrounding plateaux. The movement of the water through the sandstones, except along fissures and through particularly porous beds, is, however, very slow, so that the amount of water which can economically be made available at the surface is more or less limited, self-flowing wells being only obtainable over that portion of the area lying below the general static head.

CHAPTER XI

THE ORIGIN OF THE ARTESIAN WATERS

Flow of Water through Porous Rocks—Importance of Pressure, Porosity, and Temperature—Intermittent Flows—Abundance of Extinct Wells—Former Prosperity—Possibility of increasing Present Total Discharge — Local Traditions regarding Origin of Artesian Waters—Possible Sources of Origin—Seepage from Nile into Nubian Sandstone—Sandstones as Storage Reservoirs—The Oasis Waters of Meteoric Origin—Fissures—Rate of Flow—Strongly-flowing Wells not necessarily dependent on Fissures—Local Pressure from Variation in Level of Water-Table—Rise of Water due to Hydraulic Pressure—Points requiring Investigation—High-Level Springs: Ain Amûr; on Escarpment near Beris; at Nakhail.

THE rate of flow of water through porous rocks has been investigated by a number of engineers and geologists, among whom may be mentioned Darcy, Hazen, King, Slichter, Knibbs, and Baldwin-Wiseman. The subject is an extremely complicated one, and its study requires a combined knowledge of mathematics, physics, and geology. Various formulæ for determining the rate of flow under varying conditions have been devised, but it will be sufficient for our present purpose to remark that the average velocity of water in sands does not appear to be more than 3 or 4 kilometres a year.

The importance of porosity, pressure, and temperature on the rate of flow can be illustrated by utilizing tubes containing equal columns of sand of different degrees of coarseness, and noting the volumes of water passed under different conditions of pressure and temperature. The coarse sands will be observed to permit the passage of water at a far greater rate than the finer varieties, while any sand can be made to markedly quicken its rate of discharge by increasing the head of water in the tube above. Moreover, the rate of flow will be found to increase with the temperature of the water. In the case of the ordinary water of the oasis, a difference of only a few degrees was found to cause a very great difference in the rate of flow; it seems, indeed, as if the water, when below a certain temperature, deposits its mineral contents in the pores of the sandstone, so as to block the passages to a large extent. I have not yet had an opportunity of making the necessary experiments to ascertain if this explanation is correct, but if it should prove to be so, the importance of temperature on the rate of underground flow can hardly be over-estimated.

We have already described the intermittent character of the flow in the case of some of the larger wells in the southern part of the oasis. The circumstance is apparently due to the temporary blocking of the bore-hole by sediment, and the consequent increase of water and gas pressure below, which at intervals forces the sediment from the channels and restores the normal flow. Some-

thing of the same nature was also noticed in Bore No. 42, in the course of experiments carried out to determine the height to which the water would rise in an open pipe fixed to the end of the casing. At intervals a distinct gurgling and bubbling took place in the pipe, the water at the same time rising to as much as 8 centimetres above its normal level, with distinct oscillations of a pressure-gauge attached to the well. The ebb and flow did not, however, take place at regular intervals, but at periods varying from four to nine minutes. I think a sufficient explanation of these phenomena is the probable variation in the amount of gas finding its way into the bore; and certainly, after several years' observation of the flows of a large number of bores, I cannot admit that there is the slightest evidence in favour of the view that the flows of the wells have a periodicity dependent on the rise and fall of the Nile.

One frequently hears it stated that the oases were far more thickly populated and better watered in olden times than at the present day. This belief is based on the existence in many parts of the depression of extensive remains of temples, forts, and villages, on the widespread traces of formerly cultivated lands, and on the abundance of sanded-up wells. It must not, however, be forgotten that the remains in question belong to successive generations, and that there is as yet no evidence to enable us to determine how much of the land, or how many of the wells, were in use at one and the same

time. The evidence is, however, sufficiently pronounced to justify the conclusion that under the Romans the oasis of Kharga was far more flourishing than in modern times, a large part of the population being engaged, not in agriculture, but in mining, boring, and in the excavation of subterranean aqueducts.

We have heard the most diverse and dogmatic opinions as to the feasibility of restoring the oases to their supposed former prosperity. For my part, I do not think that there is the slightest doubt that the total discharge of water could be very much increased, though to what extent it is impossible to say with the information at present available. One must consider the vast areas under which the water-bearing sandstones are known to extend, and the comparatively small extent of country over which the existing wells occur; that as yet the deepest bores have only penetrated the water-bearing beds to a depth of 122 metres; that the existing total discharge is mostly made up of insignificant flows from a great number of ancient and comparatively shallow wells, which for centuries have been subject to gradual decay; that so far as observed the flows increase in volume as deeper beds are struck; and that it might be possible to use artificial means of lifting the water to the surface, especially in districts lying above the level to which the artesian water will rise unaided. The extent to which the water-supply could be profitably augmented is, however, quite another question, and one depending

on a great number of at present indeterminable factors.

According to local tradition, the waters of the Kharga wells come directly from the Nile through subterranean passages under the intervening plateaux, and the experience of an Arab trader is frequently related in support of this idea. The Bedawi in question, while engaged in filling his water-skins on the banks of the Nile, preparatory to setting out across the desert to the oasis, let fall his 'tarbush,' which was speedily engulfed in an eddy of the river. Although much annoyed at the time, our friend soon forgot the incident, until a few days later, when he was refreshing himself after his journey at a well in the neighbourhood of Beris, the identical piece of head-gear was borne up from its depths!

Mr. Patterson, whose knowledge of the folklore of the inhabitants is unique, recently related to me the following characteristic story: The natives of Beris, as the result of opening a long sanded-up well, obtained a very large flow of water. So terrified were they at the magnitude of the discharge—imagining, indeed, that they had tapped the Nile—that a deputation was hastily despatched to the Governor of Assiut, with profuse apologies for the damage done to the river. Needless to say, the Governor was somewhat taken aback, but realizing the solemnity of the mission, magnanimously informed its members that the waters of the Nile were so abundant that they might without fear take all they required.

At present any attempt to explain the origin of the artesian waters of the oases must be regarded as little better than speculation. More information is required concerning the geology of the country to the south of the oases, and as to the relative levels of the oases-depressions and the different parts of the Nile Valley and Libyan Desert, as far south as the more elevated regions of Kordofan, Darfur, and Tibesti. Little has been written on this subject, but the source generally assigned appears to have been Darfur. Possible sources of origin lie in the rainy districts of the Sudan, in the mountainous region of Abyssinia, in the great swamps of the Upper Nile, in the Nile River itself, and in past accumulations of water absorbed from the extensive lakes which covered parts of the country in the pluvial period which preceded the existing desert conditions.

In the present state of our knowledge I am personally inclined to agree with those who regard the Nile River as a present source of supply. It is known to flow for a considerable part of its course through a valley cut out in the Nubian Sandstone, and it is believed to lose an appreciable volume of water into that sandstone, though the exact amount has not been determined. Mr. J. I. Craig, of the Egyptian Survey, has estimated that at low Nile as much as 6,000 cubic metres of water (1,320,000 gallons) per minute drains back into the river from the sandstones on either side of the reach between Khartum and Wadi Halfa,

and, as Captain Lyons remarks, this indicates that there is considerable percolation into the sandstones from the river when in flood.*

There is one point of the greatest importance to which we should like to draw attention, as it is generally entirely overlooked. The stores of water in the sandstones may represent the accumulations of hundreds and thousands of years, and the conditions to which the beds formerly owed their sources of supply may at the present time have become materially altered. It is quite conceivable that it may have required centuries or thousands of years to saturate the huge block of sandstone underlying the Libyan Desert, and even were the original sources of supply entirely cut off at any particular time, the effect on a few hundred bores, discharging only 50,000 cubic metres a day, would not necessarily be appreciable in one, or even five, centuries.

The total annual discharge of the whole of the wells of Kharga Oasis is barely equal in volume to the water which can be held by saturated beds underlying 1 square kilometre of surface, assuming the sandstone to be only 122 metres thick; that is to say, it would take between 3,000 and 4,000 years for the existing wells to discharge the water held by the beds underlying the depression alone, without considering the vast surrounding desert

* 'The Nile Flood and Rains of the Nile Basin, 1906,' Survey Department, Cairo, 1907; 'Some Geographical Aspects of the Nile,' the *Geographical Journal*, November, 1908, vol. xxxii., No. 5.

areas, where there is no reason to doubt that the water-tables are equally well developed. It must not, however, for a moment be supposed that bores would continue to discharge until the sandstones immediately surrounding them were completely depleted of water; they would, in all probability, pass into a sub-artesian condition in a very short time were the sandstones not replenished from more outlying districts.

In my opinion the subterranean water of the oasis is certainly of meteoric origin—that is to say, it is water which originally fell as rain, and has percolated underground from one of the possible sources above mentioned. It will, however, readily be admitted that the ordinary explanation of the flow and origin of artesian wells in regions of moderate or abundant rainfall, situated in well-defined basins, where the exact position, extent, and absorbing capacity of the water-table outcrop can be carefully determined, may be in some respects inadequate to account for the flowing wells of vast arid regions like the deserts of Africa and Australia; yet, after due consideration of the arguments for and against, I am unable to subscribe to Professor J. W. Gregory's view* that a considerable portion of the waters in such regions is derived from magmatic or plutonic sources—that is to say, has its origin in the deep-seated crystalline rocks.

It may seem at first sight almost incredible that

* 'The Dead Heart of Australia'; John Murray, London, 1906.

in those regions, where the outcrop of the water-bearing strata is so remote from the wells themselves and the dip over the intervening country so slight, the rise of the water in the wells could be due to direct pressure of water in the higher portions of the beds, unless on the supposition of large and continuous open fissures. That such fissures exist, and exist abundantly, is, I think, almost a matter of certainty; but it does not follow that their presence is essential to the production of flowing wells. Fissures are visible to the eye in the Surface-water Sandstone (which, as has been remarked, does not appear to differ in any important respect from the Artesian-water Sandstone), and it is through them that the bulk of the sub-surface water is obtained. The presence of fissures in the Artesian-water Sandstone is, moreover, in my opinion, almost demonstrated by the experiments on the mutual interference of wells. It seems hardly conceivable that the closing or opening of a bore could in the space of a minute or two affect the discharge of another well over $\frac{1}{2}$ kilometre distant, if there did not exist a more or less open and direct connection between the two.

Rapid flow through a compact sandstone is impossible owing to friction, which increases as the size of the channels decreases; but, as pointed out by Knibbs and others, the hydrostatic pressure can never entirely disappear through friction, the rate of loss of head being dependent on the rate of flow. It therefore by no means follows that a strongly-

flowing well cannot be obtained from an unfissured sandstone, for a rapid flow from the bore itself does not in any way depend on an equally rapid flow of the water through the sandstone surrounding the bore. For instance, Mr. Knibbs has calculated* that although in a 10-inch bore, discharging 700 gallons a minute from a 10-foot stratum, the water would have a velocity of $5\frac{1}{2}$ feet a second at the bore itself, at the distance of one mile it would only be moving through the stratum at the rate of about $\frac{1}{200}$ inch per second, or 18 inches an hour. In other words, water flowing through a 10-foot bed of sandstone from all sides towards a 10-inch bore, need, at the distance of one mile, only have a velocity of 18 inches an hour to produce a discharge from the well of 700 gallons a minute.

The importance of local pressure arising from variations in level of a fully saturated water-table in adjacent areas may be of itself quite adequate to cause flowing wells, especially if assisted by the presence of large volumes of gas under compression, such as occur in the Kharga waters. Another theory which has at times been brought forward as an adequate cause of flowing wells is rock-pressure—*i.e.*, pressure due to the weight of the overlying strata. The objections to this theory seem to me, however, so cogent that we may at once dismiss it from our minds. There is indeed little doubt that

* 'The Hydraulic Aspect of the Artesian Problem,' Proceedings of the Royal Society of New South Wales, vol. xxxvii., p. 30.

the waters of the oasis are of meteoric origin, have travelled immense distances underground, and rise through bores placed in favourable localities by means of hydrostatic or hydraulic pressure, acting both through the pores of the rock and through open fissures. Although the rate and direction of flow through the sandstones as a whole may remain more or less matters of conjecture, it seems probable that the water of any one bore is derived from all sides, rising as the result of the pressure exerted by the water held in the same bed situated at higher levels, whether in the immediate neighbourhood or at a considerable distance.

I am conscious of having done little more than indicate the possible origin of the oasis waters and suggest the causes to which the flowing wells are due; more than this it is at present impossible to state with any confidence. The points to which attention should be directed as likely to throw further light on the subject are as follows: The area and position of the outcrops of the Impermeable Grey Shales and the underlying sandstone, and their relations to possible sources of water, whether rain, river, or lake; the nature of the bed of the swamp region of the Upper Nile; the amount and distribution of the rainfall of all surrounding regions; the volume of water lost in the different reaches of the Nile over and above that which can be directly accounted for by evaporation and by water abstracted for purposes of irrigation; and the total thickness of the water-bearing beds, the presence within them of

impervious strata, and their relation to the underlying crystalline rocks.

High-Level Springs.

Before leaving the subject of water-supply we must briefly refer to two or three remarkable instances where water is found at very high elevations. The most important of these is on the upper road between Kharga and Dakhla, where a spring, known as Ain Amûr, occurs near the summit of the plateau at about 460 metres above sea-level. The water, which is quite potable, occupies the bottom of a hole about 3 or 4 metres in depth, at the base of a clump of palm-stubs, a few paces to the south of a solitary tree; it does not run, and the water-level is said to fall considerably in the summer. A small patch of green rushes lies a few paces to the west, and there is a good deal of scrub in the neighbourhood, from the position of which one is led to infer that there are several small springs thrown out along one of the bedding-planes, at the summit of the marly and clayey beds which underlie the limestones forming the uppermost portion of the cliff.

The high-level spring on the eastern wall of the oasis, in the neighbourhood of Beris, consists of a pool of clear sweet water at the base of a large fallen block of limestone, in a desolate rocky dingle. Ball determined its height as being 180 metres above Beris, or 260 metres above sea-level. The pool itself is overgrown with weeds, and, scattered

about on the sides and bottom of the valley, there is a good deal of vegetation, mostly in the form of coarse grasses, prickly scrub, and tamarisk bushes. Geologically, the spring appears to be similarly situated to Ain Amûr—that is to say, it emerges near, or at the summit of, the argillaceous Exogyra Series, and below the overlying Danian limestones.

The water obtainable at Nakhail, 60 kilometres S.S.E. of the oasis, also appears near the summit of the Exogyra Series, and may therefore be considered to have a similar origin to the springs just described.

These elevated occurrences, thrown out along more or less definite geological horizons, must be regarded as natural springs, quite distinct from the artificially-made wells of the oasis-floor. As the springs lie several hundred feet above the static head of the artesian water, and are separated from the water-bearing sandstones by a great thickness of argillaceous impermeable strata, it is perhaps permissible to assume that their waters are derived from an entirely different source. The occurrences known are of very limited number, and the water only appears in small quantities, so that it is not unlikely that it is derived from the very occasional rains which fall on the plateaux. A portion of these rains would doubtless find its way downwards through fissures in the limestone, and, in areas where the dip of the beds was towards the oasis, might travel underground and occasionally be thrown out as springs on the walls of the depression, at the junction of the limestones and underlying clays.

CHAPTER XII

THE ANCIENT SUBTERRANEAN AQUEDUCTS

Works of Public Utility—The System probably introduced from Persia—The Bulk of the Works carried out by the Romans —Trenches connecting Wells with Cultivable Lands—Fortress Bores and their Underground Connections—Dêr el Ghennîma—Subterranean Aqueducts of Qasr Gyb—Qasr Lebekha and Um el Dabâdib—Reopening of Tunnel by Sheikh Hassan Hanadi — Sala Abdulla — Nature of Tunnels and Shafts—The Magnitude of the Underground Works—Exploration of the Tunnels—Origin of the Water.

ALTHOUGH the Persians and Romans left abundant traces of their occupation of the country in the shape of temples, forts, and monasteries, the determination and energy with which they prosecuted the colonization and general development of the oases is best shown by their attention to works of public utility. At no period in the history of the oases has so much attention been paid to the water-supply. Not content with tapping the deep-seated sources by means of bores, they carried out underground works of considerable magnitude and involving engineering difficulties of no mean order, so as to obtain additional supplies from the sandstones lying at or near the surface. The methods employed were probably introduced from Persia,

where underground aqueducts, or 'kareez,' for the transference of water from one locality to another, have from an early date been employed. At the same time, judging by the character of the ancient buildings in the immediate neighbourhood of the most important of these works, it seems probable that the latter were for the most part constructed by the Romans.

Underground aqueducts are found to some extent in all the chief oases of the Libyan Desert, but in Northern Kharga they far exceed in magnitude anything known elsewhere. In their simplest form they consist of deep trenches connecting the wells with low-lying areas of cultivable land, the object being to tap the bores at the lowest possible levels, in order to obtain the greatest discharges. Thus, although a bore, originally sunk on comparatively high ground for the purpose of irrigating a particular area of land, might through one cause or another have ceased to flow, it could still be made available for any low-lying area farther afield by the simple expedient of tapping it below the surface by means of a trench or tunnel. This practice was frequently resorted to.

In selecting sites for their forts, monasteries, and other buildings, the Romans were naturally drawn to eminences commanding views of the surrounding country. It was, of course, desirable, and in the case of forts absolutely necessary, to have a supply of water within the building, and it was the custom, therefore, to sink a deep bore within the precincts,

generally in the centre of the courtyard. In many cases, however, owing to the elevation, the water would not rise to the surface, the supplies being drawn up by hand. In order to make the water of such a well available for irrigating the lands situated outside the fort, one or more gently inclined tunnels were excavated so as to tap the bore below the fort; the well was thus made to serve a double purpose. Excellent examples of such conduits are to be seen at Dêr el Ghennîma. Here the well is in the middle of the courtyard, and three underground tunnels converge on it from the low-lying and anciently cultivated lands to the north and north-west. Along those portions where the bottom of the channel was in soft ground, and not more than a metre or two below the surface, the conduit was made in the form of an open trench, the sides being carefully built in with stone.

When the excavation of the trenches was completed, the open portions were covered over with large flat slabs of rock, so that the channels were not only well protected from blowing sand, but quite invisible on the surface. The underground conduits at Dêr el Ghennîma were indeed quite unsuspected before they were accidentally discovered a year or two ago. The tapping of the bore within the fort had, of course, the effect of still further lowering the water-level as regards the courtyard; it is quite likely, therefore, that the inhabitants had a means of blocking the underground channel when they desired the water to rise to its maximum level in

the well. But in any case the few extra metres of distance from the surface to the water could not have been a matter of importance, as the comparatively small supplies needed for domestic purposes within the fort were doubtless raised by means of a bucket and rope attached to a windlass.

These short tunnels, tapping the water of artesian wells bored on high ground, are quite insignificant compared with the extensive systems of subterranean aqueducts driven into the solid rock in various localities in the north of the oasis. The most remarkable of these are found at Um el Dabâdib, at Qasr Lebekha, and in the neighbourhood of Qasr Gyb. They were made with the object of obtaining auxiliary supplies of water from the Surface-water Sandstone, and were especially applicable to localities where this sandstone has an extensive development and forms hills or plateaux above the general level of the floor of the oasis. Although it is difficult to believe that the supplies of water obtained were commensurate with the time and labour involved in the construction of the collecting tunnels, we may safely assume that the engineers who so carefully planned and carried out the works had fully considered the results to be looked for. The ruins of villages and the traces of formerly cultivated tracts show that sufficient water was obtained to enable fairly large colonies to exist, though after the withdrawal of the Romans these outlying districts were abandoned, the aqueducts

silted up, and the cultivated lands reverted to the desert.

The ruins of Um el Dabâdib are situated under the northern wall of the depression, and distant about 36 kilometres N.N.W. of Kharga village, the route usually followed lying between the hill-massifs of Jebel Têr and Jebel Tarif. A better route is afforded by the caravan road running from Meheriq to Ain Amûr, Um el Dabâdib lying somewhat to the north of the track at a distance of 25 kilometres from the village.

Dr. J. Ball, in the course of his survey of the oasis, visited Um el Dabâdib in 1898, and thought it possible that one of the tunnels, which he observed ran northwards from the neighbourhood of the ruins, had originally formed a means of communication with some unknown and formerly inhabited depression to the north of the escarpment. Its real nature was, however, well known to the Kharga people, and a year or two later Sheikh Hassan Hanadi, a brother of the present Omda of Kharga village, got together a number of men and cleaned out one of the tunnels from top to bottom, with the result that, after a lapse of perhaps 1,000 years, water again flowed from the mouth of the aqueduct, and enabled a small agricultural colony to establish itself on the ruined site of the original founders.

Sheikh Hassan informed me that the bulk of the work had been done under his personal supervision, by a gang of from seventy to eighty men employed throughout the hot season; he had found from

experience that the natives worked better in summer than in winter. The main tunnel was entirely cleared of clay and sand, the silted material being lifted out through the numerous man-holes or vertical shafts which connect the aqueduct with the surface above. A great deal of rough masonry work had also to be undertaken where the sandstone roof or walls had fallen in. The place was put in thoroughly good order, and all the shafts again closed, with the exception of two or three left open to permit of the descent of the men sent down periodically to examine the channel and keep it free from silted material.

When I first visited the place in January, 1905, I found the discharge from the mouth of the aqueduct was between 30 and 35 gallons per minute. A dozen acres or so of land had been reclaimed, and were tended by seven or eight men, who informed me that the crops raised there were equal to those in any part of the oasis. This I can quite believe, as, in spite of the fact that several dune-belts exist in the neighbourhood, the place is comparatively sheltered from the northerly winds by the great escarpment to the north.

The little settlement of Um el Dabâdib, with its adjoining fertile fields and fruit-garden, threaded by the life-giving stream emerging from the foot-hills of the stupendous cliffs to the north, and backed by the grim fort of bygone ages to the south, has in the midst of this desert an indescribable charm.

Sala Abdulla, old Sheikh Hassan's head-man here, proved to be a most delightful fellow, and far superior to the average native in general intelligence. He spun the most fantastic yarns about the desert tableland to the north, and—a peculiarity I appreciated most of all—without expecting me to believe him. According to Sala, traces exist of a formerly much-frequented road, said to lead to a place called Ain Hamûr, lying somewhere to the north-west of Ain Amûr. But although he himself had on one occasion set out and travelled for many hours beyond the summit of the cliffs, he had been forced to return without finding the place, the exact position of which is at the present day unknown. This out-of-the-way corner of the desert is, according to my informant, so undisturbed by man that the gazelle there live for untold periods, and only eventually succumb to old age and the increasing weight of their horns, which grow to such a size that the poor beasts are unable to move about in search of food!

On my expressing a desire to examine the underground aqueduct, Sala led the way to one of the man-holes situated a couple of kilometres to the north, near the upper end of the tunnel. Producing a palm-fibre rope from under a ledge in a cliff hard by, he attached it to a log placed across the mouth of the shaft. There was a hot, steamy current of air ascending from the man-hole, the interior of which was as black as night. Sala had, however, provided candles and matches, and when he reached

the bottom and shook the rope as a signal to me to follow, I could see a tiny speck of light in what seemed to be the bowels of the earth. Fortunately I had had a good training in the Cornish and Welsh mines at home, so that the prospect of a descent by the rope did not worry me in the least, and after scrambling into the shaft I went carefully down hand over hand.

The shaft, rectangular in cross-section, and beautifully cut through the solid sandstone rock, measured roughly $1\frac{1}{2}$ metres by $\frac{3}{4}$ of a metre, tapering gradually downwards. The first few metres, sunk through the down-wash forming the bed of a valley, were carefully built in with blocks of limestone, the bottom layer resting on the solid rock below. Rough footholds on opposite sides of the shaft facilitate the descent, and when nearing the bottom, as the rope stretched and contracted like elastic in a most unpleasant manner, I was glad to avail myself of their assistance. The shaft, which I afterwards found to have a depth of 40·3 metres (132 feet), goes down perpendicularly, and when the bottom was reached, I found myself standing in a gently flowing stream of water, which I knew continued its underground course for at least 2 kilometres to the south.

The tunnel itself is distinctly coffin-shaped in cross-section, being widest near the roof, and tapering downwards. Its average height is about $1\frac{1}{2}$ metres, the mean width near the top being about 60 centimetres—*i.e.*, it measures roughly 5 feet by 2 feet.

In some places it is even narrower, so that a man of average stature not only has to keep his head very much bent, but is also forced to progress sideways if he wishes to make his way along the channel. The place was so sultry, and the cramped position I had to assume so tiring, that I had soon had enough, and groped my way back to the base of the shaft. As I had anticipated, the ascent proved considerably more difficult than the descent, and I was not sorry when I regained the surface. After the heat of the shaft and the exertion of climbing, the outside air, despite the fact that it was an exceptionally hot day, felt bitterly cold, and the rapid evaporation from our perspiring bodies chilled us to the marrow.

Although I had vowed at the time that nothing would induce me to again enter the place, I afterwards reflected that, not having followed the tunnel to its extreme limits, there might still be further information to be gained, and at the termination there might exist an inscription, the deciphering of which would yield the much-desired information as to when and by whom the work had been carried out. Moreover, I particularly wished to ascertain whether the bulk of the water came from one particular point or whether it represented the accumulated flow from the numerous small fissures which a tunnel of such length must necessarily traverse. I therefore took the first opportunity of revisiting the place, this time providing myself with proper gear to facilitate the descent, and with

instruments to make a thorough survey of the whole network of underground waterways.

The accompanying sketch-map, reduced from the detailed plan made during my last visit, shows that there are four main aqueducts, running nearly parallel, in a north and south direction, along the sides of three separate valleys. It is, of course, quite evident that the tunnels were run under the valleys rather than beneath the intervening ridges with the express object of keeping as near the surface as possible, so as to avoid unnecessary excavation in the sinking of the vertical shafts, and to reduce the labour involved in hoisting the excavated material to the surface. The engineers were at the same time careful to avoid the actual beds of the valleys, as there the soft nature of the ground would have necessitated a considerable amount of stone pitching, without which there would have been constant falls of the loose detritus, consisting of sand and pebbles with large blocks of limestone, forming the actual floors of the valleys. Alignments were chosen along the extreme margins, the mouths of the man-holes being commenced on the sloping sides of the valleys, a metre or two above their pebbly floors. The great majority were thus excavated throughout in solid rock, the latter being, as a rule, sufficiently firm to stand without timbering or masonry supports.

Although only one of the four main aqueducts is open at the present time, the exact course which each follows can be seen from the dump-heaps

marking the positions of the shafts. The longest of the tunnels is the most westerly, measuring 4·6 kilometres from the point of origin to its exit on the west side of the ruined fort, the four together having a total length of 14·3 kilometres. The actual length of horizontal excavation is, however, considerably in excess of this figure, as there are very numerous subsidiary collecting branches ramifying from the main tunnels. Moreover, the total length given is the figure obtained by measuring along the surface from shaft to shaft; whereas, one of the most striking things underground is the markedly irregular trend of the tunnel, which frequently takes a wide bend between two adjacent shafts.

The man-holes, or vertical shafts connecting the underground waterway with the surface, served a double purpose. Through them the excavated material was hoisted to the surface, and in addition they afforded a means of ventilation, without which it is doubtful whether the work could have been carried out. The excavation of the man-holes alone must have been a gigantic task, equal to, if not greater than, that of cutting out the horizontal tunnels. The cross-section of an average-sized shaft is, if anything, greater than that of the tunnel; and although in vertical dimension the man-holes near the mouth of the aqueduct are insignificant, the depth rapidly increases in the opposite direction, owing to the upward slope of the ground-surface towards the escarpment. As

already mentioned, the particular shaft I descended had a depth of over 40 metres, and subsequent levelling, from the exit of the aqueduct to a point above its origin, showed the most northerly one to have a depth of not less than $53\frac{1}{2}$ metres (175 feet). Along this tunnel, which has a total length of 2·9 kilometres, I counted exactly 150 shafts, so that their average distance apart is between 19 and 20 metres.

That the tunnel was most carefully planned and excavated is evident from its very low and gradual slope, as is indicated by the depth of water flowing through and by the generally unrippled character of the stream. Judging by the height of the mouth of one of the man-holes near the point of origin of the tunnel, and by its depth to the stream in the tunnel below, there only appears to be a fall of 1 metre in about $2\frac{1}{2}$ kilometres, or a slope of 1 in 2,670. It is possible that, owing to the elasticity of the line used, there may be a slight error in the measurement of the shaft, but the above figure may be taken as approximately correct.

We have now enough data to calculate the amount of material excavated from these underground works, and this gives us a good idea of the magnitude of the task. The average depth of the man-holes (from the ground-surface to the roof of the horizontal tunnel) works out at 22 metres—that is to say, they represent a total length of vertical excavation amounting to 3·3 kilometres. Adding 10 per cent. to the length of the aqueduct,

to allow for the numerous bends and the side branches, we get 3·2 kilometres of horizontal excavation, or a grand total of 6·5 kilometres. From a number of measurements the cross-section of both shafts and tunnels works out at an almost identical figure—*i.e.*, three-quarters of a square metre. Thus the amount of rock excavated in this system alone is about 4,875 cubic metres, and we may safely say that the construction of the four subterranean aqueducts and the 600 or 700 vertical shafts meant the excavation and removal of over 20,000 cubic metres of solid rock.

In contemplating the time and labour involved in the excavation and removal of this great mass of material, it must not be forgotten that the latter represents the construction of underground passages over twenty miles in length, and of such restricted size that only one man could have found room to work on the face of the tunnel or shaft at a time. And although the sinking of more than one vertical shaft may have been carried on simultaneously, the cutting of the long aqueducts had almost certainly to be conducted from one side only—*i.e.*, from their exits. The accumulation of water would probably have prevented the cutting out of different sections at one and the same time by separate gangs of men.

One day, in the summer of 1908, I was foolhardy enough to follow the aqueduct to its termination, from the bottom of the ninth shaft—the one I had previously descended—and in case some future

visitor to Um el Dabâdib should feel inclined to examine for himself these wonderful subterranean works, it may not be out of place to give a brief account of my examination of the upper portion and termination of the aqueduct in question (the second, counting from the most westerly), so that he may benefit by my experience. My particular objects were to ascertain if the bulk of the water came from one or more large fissures, to determine whether any special characteristics marked the termination of the tunnel, and to discover whether there were inscriptions which would yield valuable information regarding the making of the aqueduct. My intention was to descend one of the uppermost shafts by means of the windlass with which, remembering my previous experience with nothing better than a very elastic native-made rope, I had been careful to provide myself. I reckoned that the distance thence to the point of origin of the aqueduct could not be so far as to entail any great difficulty or danger from insufficiency of ventilation.

Unfortunately descent by any of these shafts proved out of the question in the time available, owing to their mouths having been carefully closed by great slabs of rock, which I had no facilities for moving. This discovery upset my calculations in two ways: unless I abandoned the undertaking altogether, which I was extremely loath to do after coming so far, it would be necessary to follow the tunnel from the bottom of the ninth man-hole for at least 230 metres, and I had already experienced

the difficulty of progressing even a short distance in so confined a space. Secondly, there was the question of ventilation. With an open shaft near the top there would at least have been good circulation through the greater part of the aqueduct; however, I still hoped that the upper man-holes were not so tightly closed as to render the air below entirely stagnant.

One of the natives who had taken part in the cleaning out of the aqueduct many years before asserted that the air was not altogether bad, and though I could not definitely ascertain whether or no he had been to the end of the tunnel since the closing of so many of the ventilating shafts, I determined to accept his word for it, and we descended safely to the bottom. The water felt cool by comparison with the air of the tunnel, though my thermometer showed the temperature of both air and water to be identical, registering 87° F. in both cases. It was quite sweet, though a good deal of sediment appeared when the stream was stirred up.

After making a number of measurements of the shaft and tunnel, we proceeded on our way upstream. The sides of the tunnel were everywhere beautifully cut in a light brown sandstone, the direction of the pick-marks showing that it had been excavated in the same direction as that we were following—*i.e.*, from south to north. Small notches for the lights used by the workmen were plainly observable on the walls, about half-way between the floor and the roof. As a rule the tunnel maintains an elongated

oval form, wider near the top than elsewhere; along one length, however, where it evidently follows a fissure, both top and bottom taper sharply, so much so that our feet constantly got jammed in the narrow, wedge-shaped channel through which the water flows. We passed many side branches, blind alleys, in fact, and the main tunnel itself zigzagged considerably, frequently turning at sharp angles, and more than once almost doubling back on itself.

The air was bad enough at the start, but seemed to get worse as we proceeded. I trusted, however, to finding a distinct improvement in the neighbourhood of the shafts, but to my dismay each one in turn proved to be hermetically sealed with masses of rock just above its junction with the tunnel, and there was not the slightest suspicion of any circulation of air, so that the only relief they afforded was the possibility of resting in an upright position. Three hundred metres, as I afterwards calculated the total distance to be, may seem little enough in the open, but to grope one's way this distance by the light of a feeble candle along a passage so restricted that one has to proceed not only with bent head and shoulders, but half sideways, in a hot, steamy, stagnant atmosphere, is quite a different matter. My companion, being of small build and stature, was able to walk upright in comparative comfort, without continually bumping his head and bruising his shoulders, so that the want of air did not tell on him to the same extent; while I became more and more fatigued, owing to the difficulty experienced of getting

sufficient oxygen from such an atmosphere in the cramped position I had of necessity to assume. On more than one occasion I sank exhausted into the water, the huge gasps of breath which I took seeming powerless to relieve the horrible sensation of stifling, and with the unpleasant prospect of getting drowned if I escaped suffocation. Yet there seemed to be ten thousand devils tempting me onwards, and although I did not know how long life could be supported under such conditions, a mad desire possessed me to see the thing through; so that whenever I was able to progress a few yards it was towards the head of the tunnel.

When eventually we reached our destination, some 15 to 20 metres beyond the last man-hole, it was only to find that the tunnel just stopped. There was no more water emerging from the rock at the end than I had seen entering at a dozen small fissures along the course we had traversed; there was no vertical excavation downwards; there were no traces of inscriptions; nothing, in fact. After all our trouble, we had drawn a blank. Although I positively dreaded the long crawl back, the very fact that every step took us towards the fresh air made me feel comparatively cheerful. After making my examination of the end of the tunnel, however, I found the space was insufficient to allow of my turning round, so that I was compelled to proceed backwards for some distance before I found room in which to turn. I must confess to never having experienced such a feeling of relief as when we

eventually arrived at the bottom of the open shaft, and were able to fill our lungs with copious draughts of the air descending from above. We could see the tiny pin-hole of light far above us, and when sufficiently rested we swung the rope as a signal to be wound up. Although I got back to the surface none the worse for my adventure, with the exception of skin bruises, I would not recommend anyone to attempt the exploration of other similar tunnels unless there were open shafts on either side to insure some circulation of air.

It is now quite certain that the aqueducts derived their water from the numerous small fissures traversed, so that the yield of any single tunnel must have depended to a great extent on its total length. The general formation of the country determined the general direction of the tunnels, which, in order to keep within reasonable distance of the surface, had to follow the valleys. The latter, without exception in this district, run in a north and south direction, having formed at one time drainage-lines from the high plateau to the north. Many of the short branch tunnels are, however, driven along east and west fissures, though these could not be followed to any great distance, owing to the high ridges separating the valleys. It is also quite certain that the work of excavation was eventually stopped by the ever-increasing labour involved in the construction of the vertical shafts, the depth of which necessarily increased at a rapid rate as the surface of the ground rose when nearing

the actual escarpment. For instance, in the space of only 230 metres, between the ninth and the first shafts, the depth of the man-holes increases from 40 to 54 metres, and to the north of this the increase would have been still more rapid, until the amount of vertical excavation would have become altogether disproportionate to the horizontal distance gained by the aqueduct.

CHAPTER XIII

BORING METHODS: ANCIENT AND MODERN

The Skill of the Ancients in Well-Boring—Present State of the Ancient Wells—Ancient Methods of Boring—Wooden Casing—Introduction of Machinery by Egyptian Government—Native Methods of Boring at the Present Day—Cleaning of Wells—Divers and their Work—Recent Boring Operations—American Steam-driven Boring Rigs.

Olympiodorus, writing more than 1,500 years ago, remarked that the inhabitants of the oases were celebrated for their skill in sinking wells. Although at the present day a large proportion of the very ancient wells are completely sanded up, or have suffered great deterioration in respect of their flows, there are still many examples to be met with where bores, certainly between 2,000 and 3,000 years old, are still producing strong discharges of water at the rate of hundreds of gallons a minute by day and by night.

Although scores of the old wells have been cleaned out and repaired in modern times, not a single instance has come under my notice of the finding of implements used by the well-borers of ancient times. We know, however, that the bores were in practically all cases lined to a considerable

depth with wooden casing, manufactured from the wood of the doum-palm, date-palm, or acacia, which doubtless were then, as now, cultivated in large numbers in the oasis. The timber was carefully fashioned into the required lengths and fitted together by water-tight joints. During the cleaning operations to which many of the old wells have been subjected in modern times, portions of the ancient casing have frequently been extracted, and some of the examples which I have examined, especially those made of acacia, proved to be in an excellent state of preservation. The wood of this particular tree—'sunt,' as it is locally called—has remarkably enduring qualities both in and out of water, though not when subjected to alternations of wet and dry. Still, that it should in some cases have retained its original qualities since Roman times is noteworthy.

It is quite evident, from a comparison of the ancient timbering and casing with those manufactured and used by the inhabitants of the oases at the present day, that the methods of well-sinking in modern times are in many respects identical with those anciently employed. This is especially the case in sinking through the superficial strata—*i.e.*, those overlying the actual beds in which the artesian water is held—though of the methods formerly practised for carrying the bore through the Artesian-water Sandstones nothing is known.

We have little, if any, information as to how the inhabitants kept up their water-supply after the

withdrawal of the Romans. Probably there was a gradual diminution of the total output, as it is not at all certain that any new wells were subsequently sunk—at any rate, until after the introduction of modern hand-boring machinery some fifty or sixty years ago. On that occasion one Hassan Effendi, a servant of a French engineer of the name of Lefèvre, was sent out by the Egyptian Government to instruct the inhabitants in the use of the new machinery. Judging from their present proficiency in sinking wells through difficult strata with the most hopelessly worn and antiquated tackle, the natives did not take long to learn the new system. Unfortunately, when left to themselves without adequate supervision, they promiscuously sunk a great number of new bores, without regard to the probable effects on the older wells irrigating the existing palm-groves and cultivated lands, with the result that, more especially in the oasis of Dakhla, a great deal of harm was done. Whole districts suffered a general lowering of water-level, many of the wells ceasing to flow altogether. This was the direct outcome of the excessive number of new bores put down in certain districts where the inhabitants were sufficiently rich and influential to get and retain possession of the majority of the newly-imported boring-rigs.

About ten years ago I studied the method of well-sinking used in the oases, and found it to consist of a combination of ancient and modern boring practices. Owing to the difficulty and prohibitive

cost of transporting heavy steel tubes across the desert, the use of locally-made wooden casing could not be dispensed with, and as casing of this description could not possibly be made of sufficient strength to stand 'driving,' the upper portion of the well had of necessity to take the form of an open shaft carried down as near as possible to the water-bearing beds, the actual boring by means of the drilling-plant being confined to the later stages.

The first operation consists in sinking a rectangular shaft, usually 2 metres square; this work is carried out by hand, the ordinary native 'fass' being almost the only implement used. As the shaft is cut out it is timbered with lengths of palm-wood strung one below the other, to prevent the walls from falling in. The excavation is carried as deep as possible, the limit generally depending on the amount of sub-surface water met with. In the oasis of Dakhla, where the superficial strata consist almost entirely of clays, it can usually be continued to a depth of about 30 metres; but in Kharga the depth varies considerably, owing to the more frequent intercalations of water-logged sandstones. The success of the prospective bore depends to a very great extent on the depth to which this preliminary work is carried, as the succeeding strata, lying between the base of the shaft and the true artesian beds, have to be pierced by a hole unprotected by casing, and if of any very considerable thickness, caving beds are likely to greatly interfere with, if not prevent, the progress of the work.

On completion of the timbered shaft the wooden casing is placed centrally in position, so as to form a vertical pipe from the base of the shaft to the surface of the ground. The pipe may be either square or round in section, and is usually made of acacia, though hollowed trunks of doum-palm are sometimes used. It consists of a number of different sections, joined together in such a way as to leave no projecting portions either within or without, the whole length of casing thus preserving a constant diameter from top to bottom. As a rule, the joints are so well formed that the pipe is, to all intents and purposes, water-tight after a short soaking. The square variety of casing usually has an inside width of 36 centimetres, the thickness of the wood being 4 or 5 centimetres; the circular, and perhaps more common, variety is made with an inside diameter of 35 centimetres, except when required for insertion within a previously fixed string of casing, when smaller sizes have to be used. The casing, of course, eventually forms the actual channel through which the artesian water flows to the surface.

The space intervening between the sides of the timbered shaft and the central pipe is then filled in with a mixture of sand and clay, firmly packed down, so as to hold the pipe securely in position, and prevent the escape of water should any of the joints become leaky.

Up to this point there is good reason to believe that the modern practice is similar to, if not identical

with, that anciently used; but in the complete absence of evidence, documentary or otherwise, we cannot conjecture how the old well-sinkers proceeded in subsequent stages. We surmise, however, that, given sufficiency of time, they were possessed of the requisite patience and skill to overcome all ordinary obstacles—as has been the case for generations in China—and it is probable that the percentage of wells abandoned was not greater than it is at the present day in countries where well-boring has become an art, carried out by means of scientifically designed machinery.

The second part of the modern operations is conducted with an ordinary percussion hand-boring outfit of European manufacture. As the method of boring with this type of rig is essentially the same all over the world, we only propose to describe it in brief. The proceedings commence with the erection of a timber framework, or derrick, immediately over the mouth of the pipe; at the summit of the derrick is a pulley, over which passes the rope or chain which connects on one side with the drum of the winch, and from the end of which, on the other side, are suspended the actual tools with which drilling is continued. The boring-rod is made up to the required length by screwing together a number of 10-foot sections, the terminal length being a shorter rod fitted with a chisel, auger, or sand-pump, according to the work in hand.

The rate of progress depends to a great extent on the rapidity with which the blows of the chisel

are delivered. This, of course, varies considerably, depending on the depth of the well and consequent weight of the rods in use. Where the weight is great and the formation sticky, the rods have to be lifted by means of the winch, and not more than two or three blows a minute can be struck. When the rods are light or working freely, as, for instance, when drilling in sandstones, the winch can be dispensed with, and the necessary motion conveyed by means of a lever actuated by a number of men. In this way progress can be very much accelerated, as many as twenty or twenty-five blows being delivered per minute. At the best, however, the method of drilling by percussion with a solid rod is necessarily slow, owing mainly to the fact that the terminal tool cannot be changed or withdrawn without the entire length of rod being taken to pieces. It is seldom, therefore, that a well of 120 to 150 metres is completed in less than five months, and the average time taken is more like nine months or a year.

It will readily be admitted that this method of sinking wells is in many respects well adapted to the local conditions obtaining in such isolated localities as the oases, where time is of little consequence to the inhabitants. The completed wells are frequently equal in almost every respect to those put down by means of the most up-to-date appliances; in fact, the only objections to the method are its slowness, the limited depth to which it is applicable, and the difficulty of fixing to the

wooden casing satisfactory appliances for regulating the discharge.

The patience and industry of the inhabitants of the oases are well exemplified by their unceasing attempts to maintain undiminished the water-supply on which their very existence depends. The population must always have borne a direct ratio to the total discharge of the wells, as on the latter depends the amount of food-supplies which can be raised. At no period, as far as we can judge, has the output of the wells been greater than the requirements, and it is probable that there has always been a population somewhat in excess of that which could be supported by local products, the surplus portion being disposed of by emigration to the Nile Valley.

The methods of dealing with wells in which the flows have diminished or altogether ceased are of considerable interest, as they have given rise to a class of men called 'ghattasin' (divers), which one would never have expected to find in such remote and arid localities as the oases of the Libyan Desert.

It is seldom that the poorer inhabitants can command the use of a hand-rig for the cleaning of their wells, so that they usually have recourse to appliances of the most primitive description. Perhaps the simplest form consists of a short iron rod, a sort of crowbar or jumper, suspended from a palm-fibre rope, and with a tiny basket attached

to the lower end. In some cases the end of the jumper is itself fashioned into the form of a cup, so that the basket of plaited grass or palm-leaf can be dispensed with. The rod is worked up and down in the bore, so as to stir up the sand and clay at the bottom, which settles in the basket or cup, and is periodically hoisted to the surface. The rope is worked over a wooden roller fixed alongside the mouth of the well, a contrivance which enables the up-and-down motion to be given with a minimum of energy and friction. The process is often continued for years, the material which can be removed in a day only amounting to a few handfuls.

The above method is only applicable to bores in which the wooden casing is more or less intact. Where the latter has rotted and allowed the sides of the well to collapse, a much more difficult and complicated procedure is necessary before the discharge can be re-established. In a case of this sort the original rectangular shaft has to be entirely cleared of material, and a new string of casing placed in the exact position occupied by the original pipe of the well. Moreover, the timber of the shaft itself has generally to be repaired or entirely renewed, as otherwise there would be very great danger of the sides collapsing when the material from within was removed. The process is rendered extremely difficult and laborious by reason of the entire work having to be carried on under water. Although a well may have stopped flowing, the passages are never so completely blocked as to alto-

gether prevent the water from rising to within a few feet of the surface, and any excavation made will always be found to become speedily filled with water. The work can, therefore, only be carried out by men who have trained themselves to remain and work under water, and a limited number of these divers are found in most of the Egyptian oases.

I have frequently watched and chatted with the divers at work on old wells, both in Dakhla and Kharga. Unlike the usual custom of remunerating men employed on well-cleaning by shares of the resulting water, divers are generally paid in cash at the rate of about a shilling a day, each man receiving his food as well. The descent is always made feet first, hand over hand down a rope stretched from the top to the bottom. When the diver wishes to return to the surface he signals by a motion of the rope to those at the top, who promptly haul him up.

The rate of progress depends, of course, on the depth at which the work is proceeding. In a well I once visited near Hindaw, in the oasis of Dakhla, divers were working at a depth of 29 metres. Each man descended six or seven times a day, remaining on each occasion from two to two and a half minutes under water. Work had been in progress here for four years, and the excavation was still 16 or 17 metres from the bottom of the shaft.

The excavated material is placed in baskets, which, when full, are drawn up by hand. As soon as

the shaft has been cleared to the bottom the new casing is inserted, the intervening space filled in, and the work carried on as in a new bore. Many extinct wells have thus been put into good working order, though in some cases the divers have been unable to overcome the difficulties encountered, and the wells have been finally abandoned after months, or even years, of labour.

In the reclamation operations conducted in the oasis of Kharga during the last two or three years, both hand and steam boring rigs have been employed, steel casing being used for all wells. The cost per foot drilled is somewhat in favour of the hand-rigs, but the rate of progress is far more rapid in the case of the steam-driven machines. The method used with the hand-machines is the same in principle as that employed by the natives and already described, with the exception that the preliminary excavation is dispensed with, the bore being drilled from the surface and lined with metal casing down to the Water-bearing Sandstones. The casing is driven by means of a heavy weight, or 'monkey,' attached to the boring-rod.

The steam-rigs used are of American manufacture, and of the design usually employed in the oil-fields of the United States. The method is a modern adaptation of a practice employed from very early times in China, free-falling tools attached to a flexible rope being used in place of a solid iron rod. The actual drilling tool, which is of great

weight, is suspended from a cable, and worked by steam-power in such a way as to give a rapid succession of blows of such force as to cut out a circular hole through the hardest of rocks. The outfit consists essentially of a very high derrick, a large drum on which the cable is wound, and a specially-designed engine worked by steam, the boiler in which the latter is generated being usually placed on a separate carriage. A second and smaller drum is provided for a fine wire rope, which is used with various forms of sand-pump for cleaning out the loose sand or sludge formed by the drilling tool.

These steam-rigs necessitate the employment of skilled drillers, and are, moreover, with difficulty kept in proper repair in out-of-the-way localities. Their initial cost is high; they are extremely cumbersome to drag from one site to another over the soft surface of the desert, and they consume a large quantity of fuel. These drawbacks are, however, partly, if not entirely, counterbalanced by the rapidity with which the work can be carried out, the average rate of progress under the conditions met with in the oasis being 5 to 7 metres per 'shift' of eight or ten hours. In the water-sandstones I have known Mr. B. F. Whiting, who was recently my drilling superintendent in the oasis, carry a bore down as much as 20 or 25 metres in a single shift. Breakdowns are, of course, not infrequent with this system of boring, but the American drillers are remarkably proficient in the recovery of lost tools.

CHAPTER XIV

THE CONTEST BETWEEN MAN AND WIND-BORNE SAND

The Winds—Wind and Sand as Agents of Denudation—The Combat of the Inhabitants with Sand-laden Winds—The Dune-Belts—Origin of the Sand—Composition of Dune-Sand—The Forms of Dunes—Dimensions and Rate of Movement—Irresistibility of Blown Sand—Protection afforded by Topographical Features—Effect of Artificial Obstructions on the Formation of Dunes—Fixing of Dunes by Vegetation and Moisture—Storm-Walls and Fences—The Dunes of Gennâh—Wind-borne Sand beneficial in the South of the Oasis—Formation of Terraces of Wind-borne Materials—Encroachment of Dunes in the South of the Oasis.

No one who has sojourned in Kharga long enough to compare it with other parts of Egypt will feel inclined to dispute the statement that the depression is one of the most windy places in the country. Only one day in ten or eleven is calm, though if the wind has been blowing fairly steadily during the day it generally drops at night. Five times out of six its direction is from the north, and when unaccompanied by sand the wind acts as a welcome moderator of the temperature.

In a desert region, owing to the surface being

unprotected by vegetation, there is nearly always an abundance of weathered material loosely exposed on the surface, the lighter portions of which are quickly swept up and carried along as soon as the wind attains even a moderate velocity. On the actual dunes even a light breeze is sufficient to set the surface-layers in motion, while on the open plain the wind becomes visibly charged with sand directly it attains the velocity of a moderate breeze. The frequency with which the wind blows has already been mentioned, and when we add that on one day in three it attains a velocity sufficient to enable it to easily carry sand in suspension, its power as a transporting agent can readily be conceived. Not only does the wind carry the sand along from one place to another, dumping it behind or in front of every obstacle it may meet, but the combination of sand and wind forms a denuding force of no mean power, capable of planing and grooving the exposed surfaces of the hardest of rocks.

Now, although opinions may differ as to the part played in the past by wind and sand in the shaping and formation of the oases-depressions of the Libyan Desert, there can be no question of the effects they are producing at the present day. Wind-borne sand is indeed the curse of the oasis, and although its evil effects may be mitigated or altogether staved off for a time, the longer this force of Nature is opposed by man the greater and more overwhelming is its final victory. If a full account of the

human occupation of the oases could be written, it would be very largely the history of an incessant combat between man and Nature; and although man may for a time gain the upper hand, and even make the sand-laden winds to some extent serve his purposes, he is in the end generally forced to abandon those places in which he has been at such pains to establish himself.

In the Libyan Desert, both on the plateaux and in the depressions, blown sand has a marked tendency to collect into dunes occupying definite north and south belts of country, lying parallel to the direction of the prevailing winds. This peculiar and fortunate disposition depends on a number of circumstances, such as the mean direction of the wind, the points of greatest supply of the material, and on other causes which are not perhaps as yet thoroughly understood.

In Kharga Oasis the best marked and most important belt lies somewhat to the west of the central axis of the depression. At the north end, in the neighbourhood of Um el Dabâdib, it consists of a number of isolated but parallel lines of dunes, which southwards pass over and round the hill-massif of Jebel Tarif, eventually uniting and forming a more compact belt of sand, with an average width of 8 or 10 kilometres, which continues right through the depression into the desert to the south. This line of sand sets a limit to the extension of cultivation to the west. A second belt comes from the plateau to the north of Qasr Lebekha, passes immediately

to the east of Jebel Têr and the village of Kharga, and continues southwards until it spreads out and is arrested, more or less by artificial means, in the vicinity of Gennâh. Other smaller and less defined belts exist to the south of Ain el Tawîl, to the east of Headquarters, and near the foot of, and parallel to, the eastern wall of the depression.

Although it has been stated by more than one writer that the great sand accumulations of the Libyan Desert originate in the denudation of the Nubian Sandstone which occupies large areas to the south of the oases, I have never myself met with any evidence in support of such a view. In my opinion the bulk of the sand must be regarded as originating in the arenaceous deposits of post-Middle Eocene age, which largely occupy and are exposed on the surface of the country between the Mediterranean Sea and latitude 29° N. We know from personal observation that some of the great sand-belts, which cross the intervening limestone plateau to the southern oases, commence in this region, and the supply of sand made available by the denudation of the beds in question is inexhaustible. During the passage of this sand across the great desert tableland the individual grains of silica doubtless become much rounded and reduced by attrition, though the total loss is probably more than counterbalanced by the very considerable additions received in the form of calcareous grains, derived from the limestones forming the surface of the high desert.

An examination of the dunes of Kharga Oasis at

once shows that the sand is not by any means composed solely of siliceous grains, but that there is a considerable proportion of white granules of limestone. A number of samples collected at random from the dunes in the central part of the depression were all found to contain a visible proportion of calcareous grains, and one of these, collected from the big dune to the south-east of Headquarters, was qualitatively examined for me by Mr. Garsed, and shown to contain 7·7 per cent. of calcium carbonate. It would be difficult to account for the presence of these calcareous grains on the assumption that the sand is derived from the Nubian Sandstone, though the denudation of the latter in and to the south of the oases must give rise to a very large amount of siliceous sand, which goes to swell the bulk of the dunes which have invaded this country from beyond the limestone plateau to the north.

The dominant form of dune in the oasis is of crescentic or horse-shoe shape, a form specially typical of desert regions where there are prevailing winds in any one direction. These 'barchans,' as they are called, which are always disposed with the concave, steeply-inclined sides facing southwards, are found of every size, and exhibit many variations of the simple crescentic pattern. In many parts of the oasis the sand-belts are made up of a number of isolated and promiscuously disposed barchans; in others the dunes have joined together into a compact mass, in which the typical shape of the individual barchan is more or less obliterated.

Solitary barchans, being well-defined isolated masses, lend themselves to observation better than the large and continuous belts of sand. They occur of all sizes, from little baby crescents, a metre or two across, to enormous masses 30 or 40 metres high and 200 to 300 metres in breadth. In all cases, except when their steady march southwards has been temporarily interrupted by southerly winds, the southern face, flanked by the horns of the crescent, is a straight slope of from 30 to 33 degrees, its inclination is, in fact, the angle of rest of loose dry sand, and it is formed of the sand which is continually blown up the opposite slope and dropped over the crest.

In a moderate breeze the whole barchan progresses steadily in a southerly direction without loss or gain of sand; in stronger winds, while still continuing its course, the dune may at the same time be either losing or gaining in actual bulk. The rate at which the barchans travel varies with their size. The larger the dune the greater the amount of material to be moved, so that, as a general rule, small barchans progress much more rapidly than large ones. The actual rate may vary from 10 to 20 metres per annum, the average being about 17. For instance, the big isolated dune on the road between Headquarters and Kharga village moved 11 metres southwards between December 8, 1907, and December 8, 1908, while during the same period a small dune in the Bellaida district travelled 21 metres in the same direction. The dimensions of these two dunes is as follows:

	Kharga Road Dune.	Bellaida Dune.
	Metres.	Metres.
Vertical height of centre of crest ...	17	10·5
Maximum breadth (east and west) ...	259	160
Maximum length (north and south) ...	230	70

These are merely instances from dunes which I have had under observation for a number of months, full details of which I hope shortly to publish.

Approached on a bright sunny day from the south side, the angle of slope within the crescent of a barchan is most deceptive. Nine out of ten persons will confidently state that the face of the dune cannot be less than 60 or 70 degrees from the horizontal, though, as a matter of fact, it never exceeds by more than two or three degrees a third of a right angle. Unless held together by vegetation or compacted by moisture, it cannot exceed the angle of rest of dry blown sand, which is about 32 degrees. In normal weather this face of a barchan is a straight, unrippled, even slope of loose sand from top to bottom; when a light or gentle breeze is blowing from the north, the dune can be seen 'smoking' at the top of the crest, the sand being blown up the much more gentle and markedly rippled northerly slope, and dropped over the crest on to the steep, smooth, southerly face. The bulk of this sand in a light breeze falls on the upper part of the slope, equilibrium being adjusted from time

to time by a downward sliding of the superficial layers. A cross-section of the dune, from north to south, would indeed show it to be composed of well-stratified layers of sand, dipping steadily southwards at a little over 30 degrees.

In this district I have never observed southerly winds hold for a sufficient length of time to do more than slightly modify the general form of a barchan, though during their continuance the progress of the dune is arrested, the outline of the crest becomes considerably altered, ripple-marks appear on the steep southerly face, and an apron of sand of greater or lesser dimensions forms at its foot.

The irresistibility of drift sand is well seen where isolated hills lie in the path of the dunes. When such hills are narrow, and elongated in a north and south direction, they generally act as a wedge, divide the wind, and force any sand it may be carrying to pass on either side. When, however, a hill has northerly flanks of any considerable width, it will only form a temporary check to the southward passage of the sand. The progress of the latter may be arrested for a while, until hollows have been filled in and the general slopes reduced; but eventually the sand will pass up along the lines of least resistance to the summit. This is beautifully illustrated at Jebel Tarif, the great isolated, flat-topped, hill-massif lying between Um el Dabâdib and Kharga village, standing over 300 metres, or 1,000 feet, above the surrounding plain. Instead of being diverted by this obstacle, the sand, coming

from the plateau to the north and north-west of Um el Dabâdib, surmounts the slopes, and continues in its normal direction across the flat-topped summit. The latter has been cut up into numberless parallel north- and south-disposed ridges, separated by deep troughs, which are now to a considerable extent filled with sand. Active erosion must, therefore, at the present day be confined to the upper portions of the slopes of the valleys and to the intervening ridges.

Naturally in such a region the inhabitants have been quick to take advantage of any protection afforded by topographical features, and it is not surprising to find that the most important of the ancient monuments, as well as the greatest area of modernly cultivated land, lie in a comparatively sheltered position to the south of Jebel Têr. Even there, however, trouble is constantly experienced on the east side, owing to the tendency of the belt of sand-dunes, which comes from the vicinity of Qasr Lebekha, to spread laterally. Along the east side of the village the dunes are close up against the outlying houses, and the sand continually surmounts and pours over the walls which from time to time are erected by the natives to act as barricades.

Sheltered places of the above description are rare, the majority of the smaller settlements being situated on the open plain, where the only precaution which can be taken is to select the sites for wells as far away as possible from the well-defined

sand-belts. But in windy weather the sand-blast is not confined to the neighbourhood of the dunes; the wind rages across the open plains, carrying dense clouds of sand in suspension, and devastating the works of man wherever the latter offer the slightest obstacle to its progress.

In order to protect his crops from the fierce onslaught of wind-borne sand the native is compelled to erect fences and barricades along the northern boundaries of his fields. These serve his purpose for the time being, the sand which would otherwise have cut and beaten down the growing crops being deposited on either side of the fence, where the velocity of the wind is checked. The arrested sand accumulates with increasing rapidity as the size of the obstruction becomes greater, a veritable dune, constituting a really efficient protection to the cultivated lands, being formed over the site of the original small and insignificant hedge. Unfortunately, this sand continues to collect, and although the cultivator may have satisfactorily insured himself against the frequent damage caused to his crops by their exposure to wind-driven sand, he is now confronted with the still more serious prospect of having his lands overwhelmed by the ever-increasing dunes, which have grown to considerable proportions as the result of his efforts to protect himself.

Fortunately for the occupiers of these outlying settlements, the progress of such dunes, formed more or less artificially on the northerly sides of the cultivated tracts, is not at the same rate as

that of isolated dunes moving across the open desert plain. Owing to the presence of a certain amount of moisture in the superficial layers of the ground in the neighbourhood of the wells and the cultivated lands, plants of various kinds are enabled to thrive, with the result that the dunes become to some extent 'fixed' by wild vegetation. The most valuable plant in this connection is the tamarisk, which by means of immensely long roots continues to thrive and keep its head above growing dunes with remarkable facility. To a certain extent, moreover, the moisture from the soil itself rises by capillarity into the base of the sand, and assists the vegetation in binding it into a compact mass, which is not liable to movement in the same degree as dry sand. The rate of progress of such dunes may therefore be reduced to a considerable extent, but the movement can never be altogether stopped. As we have seen in the case of the hamlet of Meheriq, the sand eventually gets the upper hand, blotting out the arable lands, burying the palm-groves, and forcing man to abandon his habitations.

In the neighbourhood of the Corporation's Headquarters a considerable area of the floor of the depression has been brought under cultivation during the last three years. This tract is exposed on every side, there being no protection whatever in the shape of natural features. Although occasional sandstorms are experienced from the south, and even from the east and west sides, practically

the whole of the trouble encountered comes from northerly sandstorms and sand-laden winds. It was found quite impossible to raise crops unless the fields were protected by storm-walls or fences, the young plants being cut down as if by a scythe. So long as the reclamation of land proceeded from south to north at a fairly rapid rate, the accumulation of sand against these fences was of little moment, being, indeed, rather welcome than otherwise, as the sand was found to be of considerable value when spread out and ploughed into the heavy clay soil with which this area is superficially covered. When, however, a storm-wall remains for several consecutive months exposed to the open desert to the north, the accumulation of sand becomes a more serious matter, and care has to be taken to avoid the formation of dunes, which it might be afterwards difficult to get rid of. A fairly satisfactory mode of procedure is the planting of narrow belts of 'sesban,' or other quickly-growing shrub, along the northern limits of the newly reclaimed lands; a hedge of this description forms an efficient shelter to the fields, while at the same time it allows a good deal of the sand to filter through and become absorbed by the soil.

Most of the dunes in the Gennâh district are more or less covered with tamarisk and other wild vegetation, but that their progression southwards has only been retarded, and not prevented, is evident from an examination of the country. Large areas

of land have been abandoned owing to the invasion of the dunes, and the magnificent wells of Gennâh are threatened with destruction within a very short term of years, unless special measures are adopted to cope with the advance of the sand. The available land in the vicinity of the village has long been insufficient to utilize the water discharged by these wells, which has in consequence to be led by a channel of several kilometres in length to lower ground south-east of the Gorn el Gennâh. This channel is being constantly pushed to the south, and as the ground rises in that direction, it may eventually become impossible to maintain the conduit at a sufficiently low level to carry the water of the wells to this outlying district.

The southern portion of the oasis is the only area where sand and wind can be said to be of any actual benefit to the inhabitants, but in this area, owing to the broad plains of alluvial clay, the suspended material consists to a very great extent of fine argillaceous particles. At many of the wells in the Dakhakhin and Beris districts the cultivators encourage the gradual deposition on their fields of the sand and clay-dust borne by the northerly winds. The mixture forms an excellent loam, and an annual dressing of the material is regarded as desirable, and even necessary, on account of its value as a fertilizer. The result of this gradual deposition of wind-borne material has been that the cultivated terraces have in many cases attained to such elevations that the discharges of the wells

have suffered very considerable diminution, owing to the increased height of the outlets.

To the west of the villages of Maks and Beris the great belt of sand has already enveloped a number of wells, and appears to be still encroaching —as the individual dunes follow their normal course in a direction slightly east of south—on the area occupied by the existing cultivated lands. Fortunately there are still extensive tracts of cultivable land comparatively free from accumulations of drift sand, and doubtless the inhabitants, when driven by the irresistible forces of Nature from the localities they now occupy, will again, as they have so frequently been compelled to do in the past, migrate to pastures new.

CHAPTER XV

SOME ECONOMICAL ASPECTS OF THE OASIS

The Staple Crops of the Oasis—Rice the Summer Crop in Northern Kharga—The Value of Rice in the Reclamation of Land—The Date Harvest—Conditions under which the Date-Palm flourishes—Varieties—Propagation—The Doum-Palm—Lucerne—Its Value in Land-Reclamation—The Vine—Oranges and Other Fruits—The Wadi Molûk—Earthy Minerals — The Ancient Alum Mines — The Phosphatic Deposits.

THE staple crops of the oasis are dates, rice, wheat, and barley, while for fodder large quantities of lucerne are grown. It seems at first sight a curious anomaly that in an arid region, where water is so scarce and precious a commodity, rice should be grown as the summer crop. Few, if any, plants require such an abundance of water as rice, which from the time of sowing to that of reaping has to be continually irrigated by fresh water, the fields being, indeed, during the whole period that the crop is on the ground, in a constant state of saturation. Rice does not thrive in stagnant water, and it is noticeable that the best crops in the oasis are raised on lands which have a decided slope, and over which fresh water can be kept constantly running. The proper irrigation of a rice-field is a

matter of no small difficulty, and the ingenious manner in which the oasis cultivator lays out his irrigating channels and subdivides them by means of notched weirs, so as to insure every portion of the crop getting a continuous supply of fresh water, is well worthy of close examination.

In the Nile Delta, according to Sir William Willcocks,* rice requires about twice as much water as the other commonly-grown crops, but in the oases I do not think I am mistaken in saying that it needs three times as much as any other grain. Rice appears to have been grown from time immemorial, and certainly at the present day the inhabitants would as soon think of giving up their date-trees as of replacing it by any other crop. Now, however, that facilities exist for the export of farm-produce to the Nile Valley markets, it will be interesting to observe whether rice will to any extent be replaced by more valuable crops.

In Upper Egypt the summer crop is largely durra millet (sorghum), but this plant does not thrive in the oasis, though whether on account of an uncongenial soil or owing to unsuitable climatic conditions I am unable to say. It has frequently been tried—in fact, small areas are annually planted, but never produce crops—at any rate, in the northern part of Kharga—in any sense comparable with those of the Nile Valley. The very fact that durra cannot be satisfactorily grown suggests a

* 'Egyptian Irrigation,' second edition, E. and F. N. Spon, Limited, London, 1899.

probable reason why rice, the least valuable of the Egyptian cereals, and the one requiring most water, is so universally grown in Northern Kharga. Rice, as is well known, will grow on land containing a proportion of salts which would be injurious, or even fatal, to the majority of crops, and will at the same time exercise a beneficial and cleansing effect on such land. The growing of rice may therefore have come about through the actual necessity for a periodical cleansing of land, which would otherwise have become salted to a sufficient extent to adversely affect other crops grown on the same ground. At the present day, barley and wheat alternate with rice.

The thorough and prolonged soaking to which land is subject when under rice is in itself of considerable value to succeeding crops, and in the reclamation of heavy clay-lands in the Headquarters district my experience has been that as a first crop there is nothing to equal this cereal. In many cases, indeed, it was found to be the only crop which could be at all satisfactorily raised on new lands with only a moderate application of manure. A good tilth, moreover, is far more rapidly obtained than when other crops are grown, the difference in the second and third years between lands which have and have not had rice on them being most marked.

I was much surprised to find that rice is not grown in the southern districts of the oasis, with the exception of a couple of small areas near Dakhakhin. Extended inquiries failed to elicit satisfactory

reasons for this remarkable difference from the practice followed in the north, the universal reply to my questions being that they, the inhabitants, in not growing rice, were merely following the custom of their ancestors! I noticed, however, that durra was grown on a much larger scale than in the north of the oasis, and that the crops in some cases reached a fairly good standard. It seems probable, therefore, that in this part of the depression the soil is of higher average quality, so that the land, renovated by the annual deposition of a fresh layer of wind-borne sand and clay-dust in the manner already described, does not need a periodical cleansing by rice. This, at least, is the only satisfactory explanation which has occurred to me.

The harvesting of the date-crop in September and October is the most important event of the year in Kharga Oasis. A large portion of the crop is exported to the Nile Valley, the Bedawin becoming traders for the time being, and transporting the produce across the desert by means of camels. There are over 60,000 adult date-palms, the chief palm-groves being at Kharga, Gennâh, and Bulaq in the north, and at Beris in the south. The selling-price in the oasis fluctuates to some extent, but averages twenty piastres a 'weba' of between 60 and 70 pounds, the weight of a weba varying considerably according to the moistness of the fruit and the astuteness of the man entrusted with the measuring. The price works out roughly at 4 pounds for threepence.

In a book* entitled "The Great Sahara," published nearly fifty years ago, Canon Tristram gives a very full account of the cultivation of the date-palm in North Africa. The date-palm (*Phœnix dactilifera*) is a tree specially characteristic of the Sahara, where the climate is marked by deficiency of rainfall and by considerable variations of temperature. Although it flourishes best in rainless regions, the date-palm will not fruit unless its roots are well watered; it must, indeed, as the native proverb puts it, 'have its head in the fire and its roots in water.'

In Egypt there are about fifty varieties of date-palm the chief kinds in Kharga Oasis being the Saîdi, Tamar, Fâlig, and Hamrâwi. The Saîdi dates of the oases are generally considered to be superior in flavour to almost any other Egyptian variety, and have in consequence a ready sale in the Nile Valley. The other varieties are not exported to any great extent, except, perhaps, the Fâlig; the Tamar, while producing a heavier crop than the other kinds, yields fruit of comparatively poor quality, which is on that account almost entirely used for home consumption. The Hamrâwi trees are very limited in number, but produce fruit of large size and excellent flavour; Hamrâwi dates are, however, I believe, regarded as having bad keeping properties.

Dates are met with of almost every variety of

* 'The Great Sahara,' by H. B. Tristram; John Murray, London, 1860. See also 'Tropical Agriculture,' by P. L. Simmonds.

colour except pure black or white. All the different kinds ripen at or about the same time—in the early part of September. A tree will bear from eight to ten bunches, each carrying from 12 to 20 pounds of fruit, so that in full bearing it will yield from 100 to 200 pounds of dates annually. The fruit exported from the oases, being entirely disposed of in the native markets of the Nile Valley, is packed and sewn up without any special care in palm-leaf baskets. For local use small quantities of selected fruit are frequently preserved in a moist state in earthenware jars.

Date-stones cast on the ground and accidentally buried under an inch or two of soil will germinate freely, but the resulting plants are of little use. Not one in a hundred will turn out of the same variety as its parent, so that plants raised from seed must in the great majority of cases be regarded as bastards, of no value as fruit-producers. In Kharga all new trees are raised from slipped plants—that is to say, from the young shoots which spring up at the butts of the parent trees. These are detached and planted out separately on new ground. The greatest care has to be taken to protect them from hot winds and sandstorms, and they must be watered daily for a number of weeks after being planted. Growth is very slow for the first two years, and even under the most favourable conditions the trees will not commence to bear fruit for five or six years. Date-palms come into full bearing when from twenty to twenty-five years old, and may live

to a century or more. Every year the lowest ring of branches is cut off, so that the age of a tree can be fairly accurately ascertained by counting the rings of notches on the stem. The wild, unkempt, weather-beaten trees occasionally met with in outlying, uninhabited portions of the oasis have a very different appearance from the trim, erect palms of the cultivated areas.

In the oases and in other parts of Egypt a fermented liquor called 'lagmi,' with a peculiar insipid taste, is obtained by making a deep incision in the top of the date-palm, the liquid oozing out and being collected in a vessel, generally made of the rind of a gourd. As much as 10 quarts can be obtained in a day, and the tree may be bled once or twice a month without sustaining any harm; the operation may, in fact, prove of considerable benefit to a sickly palm. A very strong spirit—date-brandy—is also made from the fruit.

Tristram records that the heart or cabbage of a date-palm, which in taste is said to resemble the sweet potato, is eaten by the natives when a tree falls or is blown down. The uses to which the leaves, fibre, and wood of the date-palm are put are innumerable, and include the manufacture of such diverse articles as baskets, mats, ropes, and saddles.

The doum-palm, or gingerbread-tree, flourishes in a semi-wild state in many parts of the oasis, more especially in the tract of country lying between Gennâh and Bulaq. The fruit is brown and mealy, and, in localities where the trees are properly tended,

is said to be very nutritious, and to resemble gingerbread in taste and colour. In some parts of the Sahara the spongy internal portion of the nut forms an important article of food, and when mixed with an infusion of dates constitutes a cooling drink much valued for use in cases of febrile disorders.

Although pasture or grazing lands can hardly be said to exist in the Western sense of the term, lucerne is very commonly grown in Kharga to provide a supply of green fodder for cattle. The plant seems to be peculiarly adapted to the local conditions, and is often kept on the ground for long periods, the crop providing very frequent cuttings and improving from year to year. It is seldom or never grazed direct, probably for the reason that cattle are apt to pull the plants out by the roots, the ground on which it best thrives being very loose and sandy. In the reclamation of new lands, where the soil is deficient in organic matter and nitrogen, this leguminous plant has been found to be of very great value. Excellent results were obtained at Headquarters on desert surfaces which had never previously borne vegetation. On the more sandy areas the plant quickly established itself, becoming in the second year an even and strongly-growing crop from 18 inches to 2 feet high, yielding heavy cuttings every few weeks. For benefiting a poor soil by the introduction of nitrogen from the atmosphere probably nothing could be found to excel lucerne, which, judging by the numerous and well-marked nodules formed on the roots, acts as a

most efficient host-plant for nitrogen-fixing bacteria. My attention was first drawn to these nodules by Mr. D. Milne, who was formerly in charge of the agricultural work at Headquarters, and both he and my present assistant, Mohammed Said, an Egyptian agriculturist of wide practical experience, have formed a very high opinion of the utility of lucerne in the reclamation and fertilization of raw and new desert soils.

In ancient days the vine was extensively cultivated in the oases, and under the Romans there appears to have been a considerable trade in wine. At the present day excellent oranges, as well as apricots, mulberries, and olives, are grown in both Kharga and Dakhla, but only in comparatively small quantities, though the soil and climate appear to be eminently suited to the cultivation of fruit-trees.

Cotton cannot be said to be cultivated in the oases, as the very occasional plots one meets with are evidence that its culture is not understood by the natives, who aim at the production of wood rather than fibre. Experiments made at Headquarters, however, show that many Nile Valley crops not hitherto grown in Kharga, such as cotton, sugar-cane, and beans, can be successfully raised without difficulty.

There exists in the possession of His Excellency Johnson Pasha, formerly of the Egyptian Ministry of Justice, a curious old Arabic document, purport-

ing to describe the so-called Wadi el Molûk, or Valley of the Kings, a depression or valley in which, according to tradition, large quantities of gold, silver, and other precious metals exist. The place is described in true Oriental fashion, and the manuscript relates in detail how the route, starting from an old monastery in the neighbourhood of Esna, proceeds. According to the information given, the Wadi el Molûk would appear to lie somewhere within the desert triangle between the points Esna, Aswân, and Beris, but although a number of more or less serious attempts have been made to discover its whereabouts, this El Dorado has not yet been located. Judging by the geological conditions—so far as they are known in the area in question—one might, with equally good chances of success, search for metalliferous deposits of gold and silver in the Weald of the South of England.

Earthy minerals exist in the oasis of Kharga, and appear to have been extensively mined by the ancients in some localities. Deposits of ochre occur near several of the wells to the east and south-east of Kharga village, notably to the west of Ain Aid, to the west of Ain Khalîl, and to the north of Ain Girgâwi. The best occurrences are to the south of the Gorn el Gennâh, in which district the ferruginous waters of certain wells have deposited thick banks of ochre along their channels.

The sulphates of aluminium and magnesium are widely distributed in the oasis, though the deposits are seldom of sufficient extent to repay extraction.

They occur as thin bands in the shales and sandstones of the surface-water series, seldom exceeding a few centimetres in thickness, and being generally of very limited horizontal extent. The alum, which is often found in beautiful fibrous or hair-like crystalline masses, is frequently of a delicate rose tint, and analysis shows the colour to be due to the presence of small quantities of cobalt. Epsomite (Epsom salts or hydrous sulphate of magnesia) is also found in fibrous crystalline seams, a remarkably pure deposit, containing several hundred tons, having been quite recently located a few kilometres west of Headquarters.

In the foot-hills to the north of Bellaida, at the base of the eastern slopes of Jebel Tarif, and in the hills immediately to the west of Qasr Lebekha, ancient mines of the most extensive description are to be seen. The rocks in these localities consist of variegated sandstones and grits, many of the beds being so dark and ferruginous that the hills, as a whole, have a blackened and almost volcanic appearance. They are literally honeycombed with ancient workings, many of which, both in the form of large chambers and narrow tunnels, penetrate for long distances underground. Huge dump-heaps mark the entrances of the workings, and bear witness to the enormous quantities of 'country' rock removed in the winning of the useful mineral. The rude shelters built by the miners are to be seen in the immediate vicinity, and in many cases are still intact.

The extent and magnitude of the underground workings prove that whatever the mineral mined, it was a substance of considerable value in those days; and an examination of the blind terminations of the tunnels occasionally reveals the presence of very thin seams of aluminium sulphate, which, in the absence of indications of other useful minerals, we must conclude was the substance sought. The bands of alum were evidently followed until they thinned out to a fraction of an inch, or disappeared altogether.

A reference to the geological sequence will show the stratigraphical position of the phosphatic series of the oasis, consisting of hard bands composed of fish-remains, coprolites, and phosphatic nodules. The beds have a wide extension in Northern Kharga, and are especially well developed on the flanks of Jebel Tarwan and Jebel Têr, in the centre of the depression. As a rule, they consist of an upper brown-coloured series, individual beds of which in places have a thickness of 2 or 3 metres, and a lower division consisting of three or four thin, hard, and lighter-coloured bands, in which the phosphatic nodules are often cemented by iron pyrites. The upper bands may contain anything up to 60 per cent. of tricalcium phosphate, so that the deposit may be regarded as of considerable potential value.

CHAPTER XVI

SOME NOTES ON SPORT AND NATURAL HISTORY

The Libyan Desert as a Sporting Region—The Dorcas Gazelle —Snipe—Wild-Fowl—The Local Sportsmen—An all-night Sitting — Quail — Sand-Grouse — Rock-Pigeons — Turtle-Doves—Various—Striped Hyæna—Jackals—Three Species of Fox—The Desert Fox—The True Fennec.

SPORTSMEN who reckon the success and pleasures of a shooting expedition only by the contents of the resulting bag are advised to give a wide berth to the Libyan Desert, as in that arid region—with the exception of one restricted area far removed from the oasis under description—no game is to be found which cannot be obtained far more easily, and in much greater quantities, in the cultivated plains of the Nile Valley and on the adjoining desert margins. On the other hand, the sportsman who does not regard too seriously the actual head of game brought to bag, and who has no objection to hard work, will find in the oases undoubted attractions in the way of rough sport. Provided with a few camels to carry the necessary impedimenta, so as to be rendered independent and able to wander about at will, a very enjoyable time can be spent exploring the various isolated portions

of the depression where gazelles abound, and visiting the numerous outlying wells where wild-fowl, snipe, quail, sand-grouse, and rock-pigeons are to be met with in fair quantities.

The little Dorcas gazelle ranges over the whole of the Libyan Desert. On the plateau, owing to the extreme scarcity and scantiness of vegetation, gazelles seldom remain in the same locality for any length of time, and even when met with can rarely be approached, owing to the open nature of the country. In the more fertile oases-depressions they are to be seen in far greater numbers, especially in the outlying portions where large tracts are covered with coarse grasses, tamarisk, and other kinds of scrub. After nightfall they frequently descend to the cultivated lands to browse on the crops, almost invariably retiring to the outlying desert areas at the first traces of dawn, though I recollect on one occasion bringing a laggard to bag very early in the morning on the edge of a barley-field at Um el Dabâdib. Gazelles are, in fact, seldom to be seen, unless carefully sought for in their special haunts; one might remain for months in the inhabited portions of the depression and only be aware of their existence from occasionally meeting with their spoor.

It is advisable when hunting gazelles to pitch camp at some distance from their grazing grounds, as they are extremely wary, and not to be approached once they have taken alarm. Extensive tracts of uninhabited, scrub-covered desert, like

those to the north of Ain el Qasr, affording ample supplies of food, and undisturbed by man, are the favourite haunts of these extremely shy animals. For shooting this district an excellent camping-ground will be found on the edge of the scrub in the neighbourhood of Qasr Gyb, an ancient ruin conspicuously perched on the summit of a conical hillock, about 20 kilometres north of Meheriq. The dead parts of the scrub supply an abundance of fuel, and good water is obtainable by clearing out a section of the ancient underground aqueduct lying a short distance to the south. From the shelter of any of the higher clumps of vegetation one can, with the aid of field-glasses, keep a careful look-out over the surrounding scrub-covered country, and, once gazelles have been located, getting within range is merely a matter of patience and careful stalking. After sighting the quarry, it is best to proceed alone, as natives have an exasperating way of exposing themselves at the most critical moments. On my last visit to the north of the oasis there were a good many gazelles about, including a herd of some seven or eight; it was, however, quite impossible to get within 500 yards of these, but I had better luck with a solitary couple a few kilometres to the north of the old ruin, both of which I succeeded in bagging.

The Dorcas gazelle is one of the smallest and fleetest of the antelopes. When full grown, the buck stands about 22 inches high at the shoulder, the horns in my best head—not, however, shot in

Kharga—measuring exactly 13 inches. Properly cooked, its flesh is excellent, and certainly superior to the average Egyptian mutton.

For snipe the best time is from December to February, though I have shot odd birds as early as October and as late as April. Both the full and the jack snipe are to be met with, their favourite feeding-grounds being the rice-stubbles immediately after the crops have been harvested, and before the ground has had time to get hard and dry. In the cold weather, however, almost any wet patch—and there are numerous small bogs at the lower ends of the paddy-fields and alongside leaky irrigation channels—will yield one or two couple. Formerly there was a very useful bit of ground at Ain el Tawîl, but the best place of all is close to the village of Gennâh, where a reedy bog of considerable size at times positively swarms with snipe. This place is rather difficult to shoot, and I used to consider I had done well if four or five couple were gathered.

Pools of various size, formed by drainage waters from the cultivated lands, are found scattered throughout the oasis, and in the early morning or late evening hours quite a respectable bag of wild-fowl can sometimes, with a little luck, be secured. I say sometimes advisedly, as where duck are concerned one has to compete with the local sportsmen, whose name is legion. Mallard, teal, and shoveller ducks are the most common, though several of the other species commonly found in

the Nile Valley are also to be met with in the oasis.

The keenness of the Kharga sportsmen is well illustrated by the following incident: Encamped on one occasion for a week or two near the village, I was in the habit of pottering about of an evening with my gun, visiting the two or three pools within easy walking distance of the tents; but although there were a good many wild-fowl about, these had been worried to such an extent that they only remained on the ponds during the darkest hours of the night, preferring, indeed, to pass the day in solitude in the open desert than to turn themselves into targets for the never-ending practice of the local Nimrods. Thinking to get the better of both duck and natives, I made arrangements to visit a pool about three miles distant from the village, starting at an hour early enough to enable me to take up a good stand before daybreak. Fortified by biscuits and hot cocoa, I and my faithful retainer, Mohammed Abu Salem, left camp one chilly morning about three, riding the best part of the way on camels, over the roughest country imaginable. Half a mile from the pool we dismounted, and I proceeded alone on foot across cultivated lands, on which, to my astonishment, ploughing was already in progress, though it was still dark, wanting a full hour to dawn. Slowly and with some difficulty I made my way towards the thin streak of light that I knew marked the position of the pool, which in my mind's eye I

already pictured as covered with duck. Presently, to my surprise and disgust, a shot rang out; but this was nothing to my astonishment a few moments later, when, just as I was getting up to the water, a regular broadside was discharged. There seemed to be gunners all over the place, and my only concern now was to get out of their way as speedily as possible; so, ensconcing myself behind a small sand-hill, I lighted a pipe and awaited further developments. By careful manœuvring I was able to watch in moderate safety the glassy surface of the pond, and did not have to wait long before I heard a rattle of wings, followed by the swoop on to the water. No sooner had the birds alighted than they were greeted with a fusillade from all sides of the pool, after which silence once more reigned supreme. This performance was repeated every time duck or coot made their appearance, and few escaped the effects of the deadly cross-fire to which they were subjected.

When daylight appeared I counted over a dozen gunners squatting round the pond, although the latter measured no more than 120 to 130 yards across its widest part. They were armed with every sort of weapon, from the latest thing in cheap European breech-loaders to the most antiquated form of flint-lock, the barrel of the latter type of gun being usually of great length, and not unlike a piece of gas-pipe. As soon as daylight was sufficiently advanced, the natives proceeded to gather the slain, the bulk of the bag being made

up of coots, which at night have a habit of deserting the depths of the rice-fields for a swim and change of food on the open pools. Each man seized the birds he considered had fallen to his gun, and I was struck by the small amount of squabbling which took place over the division of the spoil, most of the bickering having reference to complaints of being peppered, though the wonder was that no one had been killed, or even seriously hurt. As soon as everything was satisfactorily adjusted the majority of the men, having salaamed and expressed surprise at my presence, made off towards the village, only a few of the keener spirits remaining on the chance of further sport. To my delight, a flight of duck shortly afterwards put in an appearance, and I was able to score by bagging a couple as they passed suspiciously over the pond. The laugh was now on my side, as I need hardly say that the native never risks wasting his powder and shot on birds on the wing, and after some mutual banter they departed, leaving me in possession of the field.

Quantities of quail pass through the oasis on their annual migration from north to south and on their return journey in the opposite direction. The best bags can be made in the spring, when the corn is commencing to ripen, but sport is usually rendered difficult owing to the number of natives at work in the fields. The local sportsmen do not seem to consider quail worthy of their attention, probably because the birds so seldom show them-

selves except when on the wing. A good many are, however, secured by the peasants in traps.

Sand-grouse are to be met with in many parts of the depression, more especially near the outlying sparsely cultivated spots, the commonest variety found being one of the pin-tailed species. The sandy country round Gennâh is perhaps the best district. Rock-pigeons frequent the cultivated lands of Bellaida, to the north of the village of Kharga, and have their homes in the rocky fastnesses of Jebel Têr and Jebel Tarif, breeding in perfect security in the fissures which traverse the limestone rocks of those hills. Turtle-doves are found in the more wooded portions of the oasis, their favourite haunts being the old spreading acacias which line the water-channels and mark the sources of the ancient wells. Although not as a rule regarded as coming into the category of game-birds, turtle-doves are by no means to be despised when one has failed to replenish the larder from ordinary sources. When disturbed in their favourite haunts, the birds fly rapidly from tree to tree, and shooting has to be both straight and quick if anything of a bag is to be made. In addition to these an occasional plover or water-hen may be met with and be considered as worthy of record in the 'various' column of the game diary.

In the Nile Valley the striped hyæna has often afforded me a day's amusement if not actual sport, but this animal is certainly not a resident in the oasis, though on rare occasions an individual crosses

the plateau and remains for a few days within the depression. Jackals are common, though not nearly so numerous as in the neighbouring oasis of Dakhla. At night they prowl about the outskirts of the villages, and the din that a single couple can make must be heard to be believed. The cry is most weird, consisting of a succession of long melancholy wails, each one a little higher pitched than the preceding, followed finally by a quick succession of sharp yelps or barks.

Of foxes there appear to be three species in Egypt, the largest and best known being a variety of the common fox (*Canis vulpes*, subsp. *ægyptiaca*). Although this animal frequently makes its home on the margins of the bordering deserts, it is never found at any great distance from the villages of the Nile Valley, to which it invariably descends at dusk, returning to its lair in the early morning after spending the night roaming the cultivated lands in search of food. The smaller desert fox, or fennec (*Canis famelicus*), is found not only on the desert margins, but throughout the interior plateaux and depressions. A true denizen of the desert, this animal seldom approaches the abodes of man, and probably never penetrates into the cultivated lands on either side of the Nile. Thirdly, there is the diminutive little fox, the true fennec (*Canis zerda*), which, although found throughout the interior of the Libyan Desert tableland, is especially abundant in the oases-depressions.

Of this beautiful species the late Dr. Anderson,

in his 'Zoology of Egypt,' wrote: "There is no authentic record of the Fennec having been discovered in a wild state by any European traveller. All the specimens which have been brought home have been obtained from Arabs." This fox is, it is true, a very shy animal, so much so that during the course of many years' work in almost every part of the Libyan Desert I never had the good fortune to observe one in its natural haunts, though its burrows were often met with, and my men at night occasionally succeeded in securing specimens in traps.

During the last year or two, however, while resident in Kharga Oasis, I have been more fortunate, having frequently observed these interesting little animals sitting near the entrances to their burrows or sniffing about in search of food on areas sparsely dotted with desert vegetation. Several pairs had burrows within a few kilometres of my headquarters, and were, I believe, responsible for fowls that disappeared from time to time from our farm-yard. Mr. P. von Adametz kept one of these tiny foxes in the mess for some time, but this particular animal, which had been caught in the neighbourhood of Meheriq, was evidently too old to become tame. Fennecs probably subsist mainly on desert gerbils and jerboas, which are always to be found in large numbers in those portions of the desert where vegetation is at all plentiful.

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